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Description of the Installations at the Pleumeur-Bodou Space Communications Station

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The Pleumeur-Bodou Ground Station, the research center of the National Center for Telecommunications Studies in the field of space telecommunications, is equipped to study all problems connected with active satellites: link performance, acquisition, tracking, telemetry, and command. This station is also intended for possible future commercial applications.

A ground Station constitutes the basic facility for experimental studies of space communications systems. In the Pleumeur-Bodou ground station, CNET (National Center for Telecommunication Studies) has a group of installations which will permit the acquisition of extensive experience in the field of communication by active satellites.

However, these installations have not been designed solely for experimental purposes: the operational status of the station has been planned for. The station is able to accommodate the equipment required for practical application of a communications system by satellite.

The establishment of a ground station at Pleumeur-Bodou was decided upon within the framework of the American projects Relay and Telstar. In the spring of 1961, the French Government signed an agreement with NASA, to associate with project Relay by putting into service a station capable of providing communication links through the satellite.

In consideration of the very short notice allowed by the announcement of the planned satellite launch date, the Ministere des Postes et Telecommunications decided to ask for the cooperation of AT and T (American Telephone and Telegraph). This company had in fact undertaken to set up an original project for communications by active satellite, the Telstar project, which included construction of a ground station which was the subject of special studies at Andover. In December 1961, AT and T signed a contract with the Administration des Postes et Telecommunications and undertook to furnish the essential elements for a station identical to the one at Andover, as well as technical assistance. CNET was to be responsible for the overall operation. The Compagnie Generale d'Electricite (CGE) participated in the capacity of industrial architects. After a period of preparation, the first construction work started in October 1961 on the selected site. On July 8, 1962, all the equipment was installed and on 9 July the system tests demonstrated that the station was operational.

The various characteristics of the ground station will be discussed: (1) The site; (2) Overall design; (3) Buildings and substructure; and (4) Operating equipment.

A more detailed description will follow of some of the equipment which is characteristic of the Pleumeur-Bodou station: (5) The command tracker; (6) Terminal equipment; (7) Simulator equipment of l'Ile Losquet (boresite tower); and (8) Power supply equipment.

THE SITE

The search for a suitable site, begun in 1961, was confined to Brittany, which, being in the westernmost part of France, would give the longest periods of visibility from both sides of the Atlantic. Also, the temperate climate of this region was an attractive consideration.

Pleumeur-Bodou was finally chosen for the location of the site for the following reasons (Fig. 1 and 2):

1. The proximity of the CNET laboratories, situated near Lannion (Research Center—Flight Testing).
2. Within easy reach of the telephone and television networks.
3. Rapid acquisition, in a sparsely populated area, of a large area on a stable granite base, affording a potential for expansion.
4. Radio interference minimized (distance from r-f beams, airports, seaports, and sea lanes) and monitored by systematic control measures.
5. Overall topography in the shape of a basin, the edges of which act as a screen which increases protection against radio interference, but which is low enough (less than 5°) not to raise the horizon.
6. Proximity of a resort-type coastal zone which offers pleasant surroundings for employees.

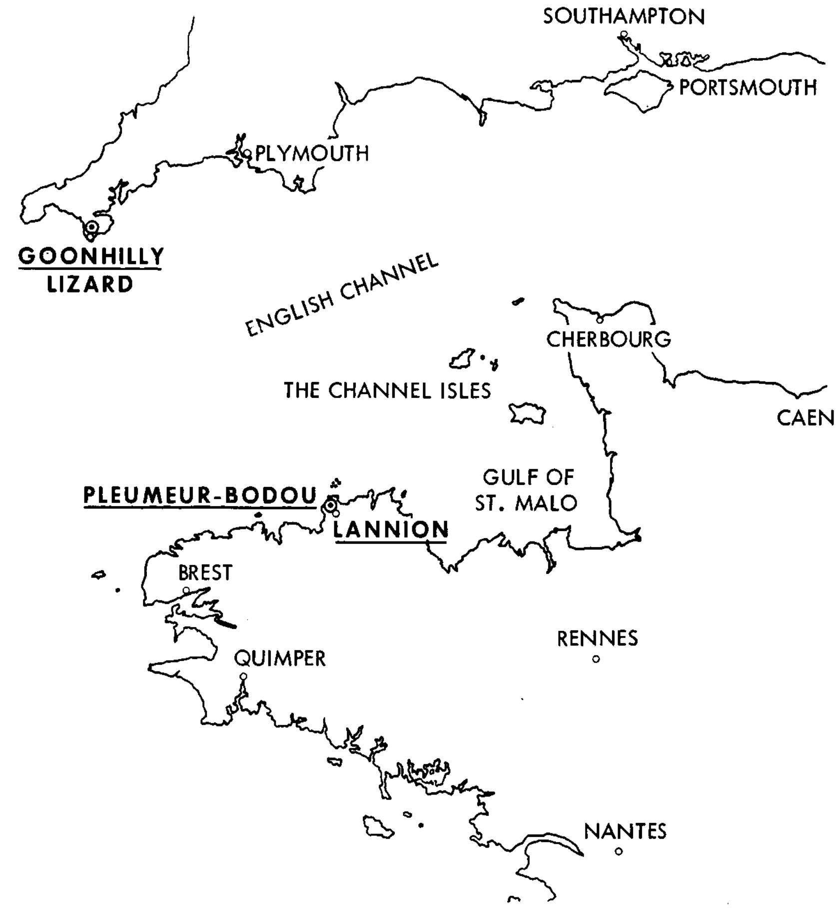


Fig. 1 — Location of the ground stations in Brittany and Cornwall.

The surface area of the site is 105 hectares. The geographical coordinates of the center of the antenna are:

Latitude 48° 47′ 13″ N

Longitude 03° 31′ 20″ W.

The average altitude is 40 meters. A general view of the station is shown in Fig. 3.

OVERALL DESIGN OF THE STATION

The performance characteristics of the station were determined by those of the Telstar satellite, and by the desired link.

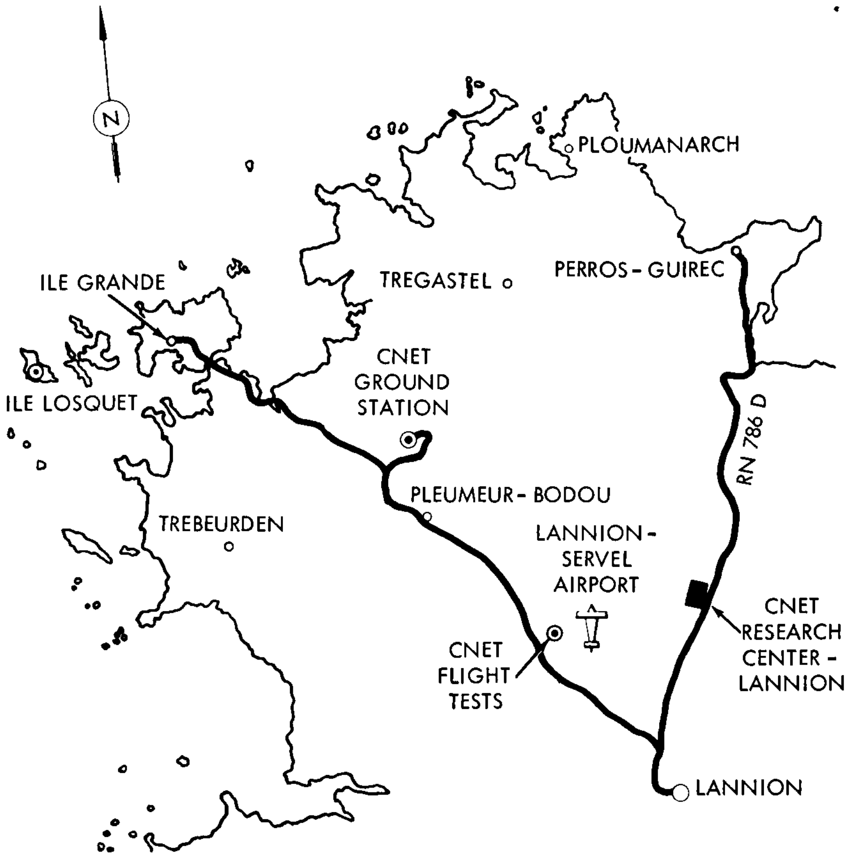


Fig. 2 — The Pleumeur-Bodou region.

The two basic characteristics of this type of link are the great distances which the signal must travel without amplification, and the fact that the transponder (i.e., the satellite) is in motion. Thus a very large and heavy antenna, which can be aimed with extreme precision, is needed.

In order for such a large facility to be commercially profitable, it must be ready to operate at all times. It must be sheltered from atmospheric conditions which might inhibit its action, the wind in particular. This is the function of the radome. Its capabilities for acquiring and tracking the satellite must be reliable; this is brought about by an acquisition and tracking system in which the antenna

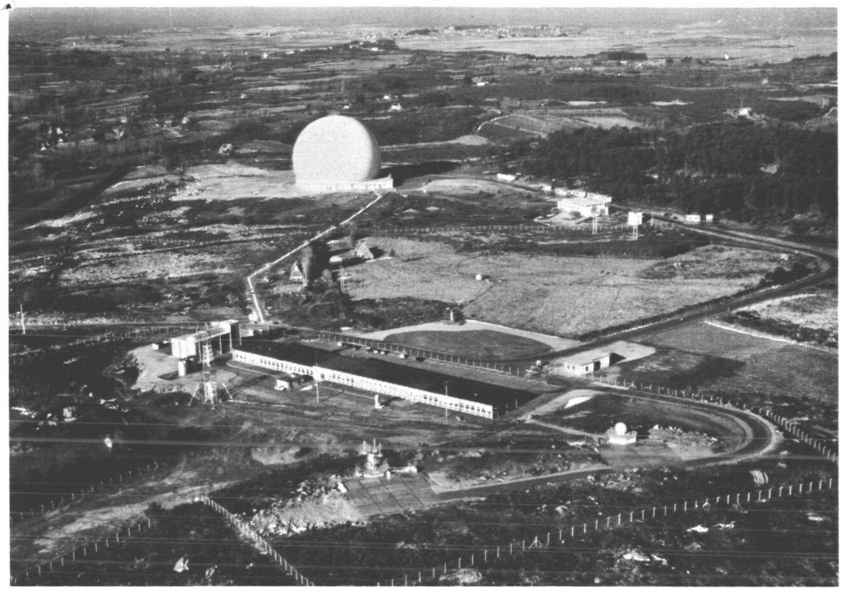


Fig. 3 — General view of the station.

equipment is complemented by coarse and fine trackers. Finally, basic equipment mentioned above must be supported by reliable auxiliary equipment.

To be able to take advantage of all the experimental possibilities of this system, the station must have facilities for receiving the satellite telemetry, and for command.

The Pleumeur-Bodou station has consequently been equipped with the following main installations:

1. Under the radome, a horn antenna with transmitter and receiver, the Vernier-Autotrack, the antenna control, and the servo amplifier for the steering motors.
2. An acquisition and command tracker, with its antenna
3. A precision tracker and its antenna
4. In the main building (centrally located):
   Antenna control systems
   Terminal equipment for connection to the telephone and television networks.
5. Facilities for testing the equipment:
   A test tower for tracking equipment.
   A satellite simulator tower for use with the horn antenna.

6. Auxiliary installations:
   Power supply
   Heating
   Air-conditioning
   Pressurization for the radome

The individual characteristics of the antenna and its steering gear will be discussed below.

The Horn Antenna

Since the antenna requires a very high gain and a very low noise, the Bell Laboratories decided on a horn antenna with cylindrical reflector, with an opening about 20 meters in diameter.

The antenna characteristics are:

	Gain	*Beam Width*
Transmission 6000 Mc	60 db	0.12°
Reception 4000 Mc	57 db	0.23°

Thermal noise, including the radome, is 19°K.

The nominal level of the signal at the entry of the receiver is −94 dbm, the threshold being −104 dbm. The antenna has a very large bandwidth and can be used for frequencies up to 10,000 Mc.

The Receiver

Nominal frequency: 4169.72 Mc.

To reduce the noise added by the receiving equipment to a minimum, the incoming signal is amplified by a maser, which operates in liquid helium and has a noise temperature of only 4°K.

The frequency excursion of the incoming signal being very large, the threshold of the receiver is reduced to its lowest value by frequency compression.

The Transmitter

Nominal frequency: 6389.58 Mc.

The transmitter power can be adjusted in relation to the distance of the satellite, from 20 w to 2 kw.

Antenna Pointing

The operation of tracking the satellite is made very critical by the great inertia of the antenna (weight: 340 tons) and by the small beamwidth (±0.12°). The antenna must be oriented both in azimuth and in elevation with an accuracy of a few hundredths of a degree.

Such precision can be obtained only with the help of digital computers. In normal operation, a data reduction center computes, from the orbital parameters, antenna pointing data at 4 second intervals. This data is recorded on magnetic tape.

At the desired time, given by the station clock, a block of data is transferred to the antenna control which stores it in a memory and interpolates at the rate of 128 points per second; the antenna control makes manual or automatic corrections to these points, and compares the result with the actual position of the antenna so as to determine the necessary corrections. These corrections, when translated into analog signals, will act as servo-mechanical commands.

The vernier autotrack (VAT) receives the 4079.73 Mc signals from the satellite beacon, evaluates the pointing deviations and adds a vernier pointing correction.

The necessary elements for establishing ephemerides are supplied from the Andover station or the NASA computing center. They can also be computed by the station computing center from data recorded during a pass.

This system of pointing, which is the operational mode when the satellite's orbit is known, is inadequate for experimentation.

Therefore, a precision tracker (PT) would be needed for use in case the magnetic tape fails. Its beam angle being 2° it can, with the aid of the coarse tracker (beam angle 20°) if necessary, acquire the satellite 4079.73 Mc beacon and track it with an accuracy greater than 0.01 deg. A track encoder processes the pointing data, translates it into digital commands, and transmits it to the antenna drive which controls the orientation of the horn antenna. The horn antenna can then either lock onto the satellite by the vernier autotrack, or continue tracking from the data supplied by the precision tracker.

The pointing data is sent by the track encoder to the computation center, where it is recorded on tape from which the orbital parameters can be computed.

By means of the two independent pointing systems, a very high degree of steadiness in satellite tracking has been provided.

BUILDINGS—THE SUBSTRUCTURES

Station Layout

The arrangement of the existing installations within the site leaves a large open area for future expansion (Fig. 4).

The tracking antennas, the main building, and the heating plant are

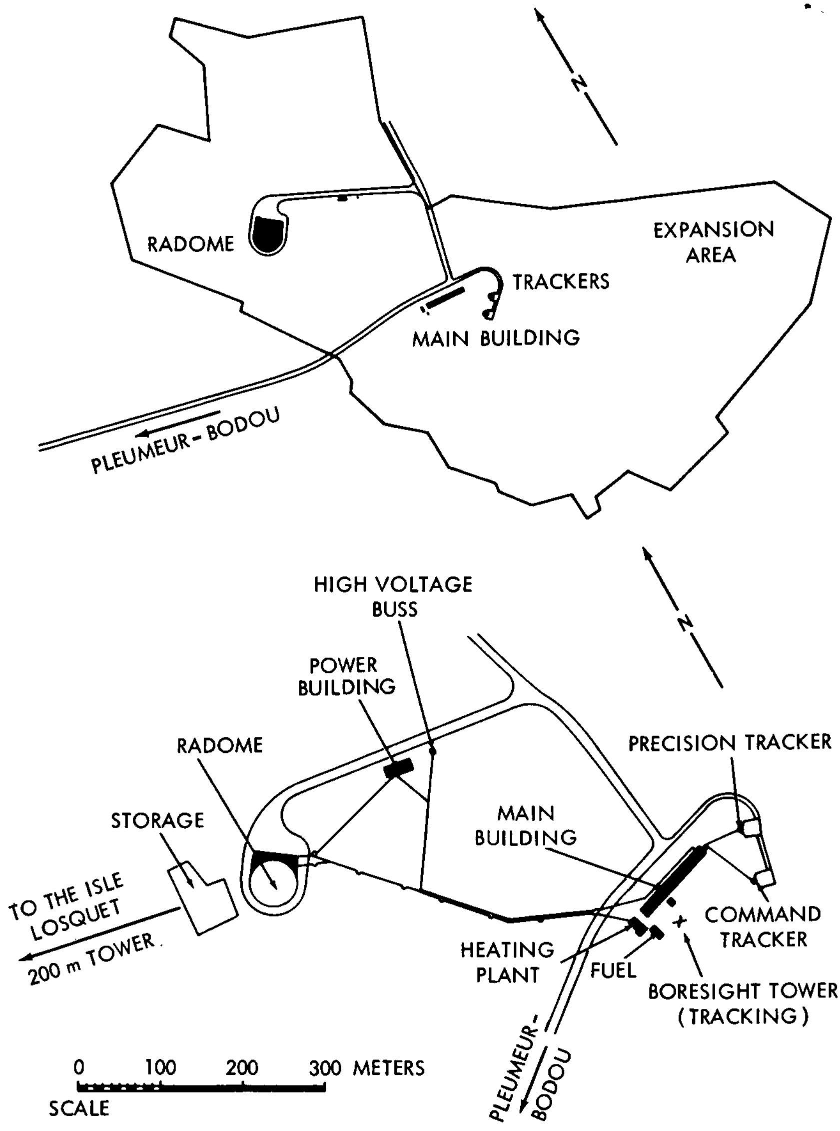


Fig. 4 — General plan of the station and location of the buildings.

centrally located with regard to the radome and the planned locations of future antennas.

To avoid air pollution from diesel exhaust affecting the radome blowers, the power plant has been located at some distance from the radome.

Radome

The radome (Fig. 5) is built in an unobstructed location. It acts as a very stable base for the antenna (track diameters: 22 and 41 meters), and insures weather protection (spherical envelope with a diameter of 64 meters—supported by a surrounding wall of 58.50 meters).

Pivot, tracks and wall foundations have large anchor sole plates imbedded in 0.50 meter of solid granite.

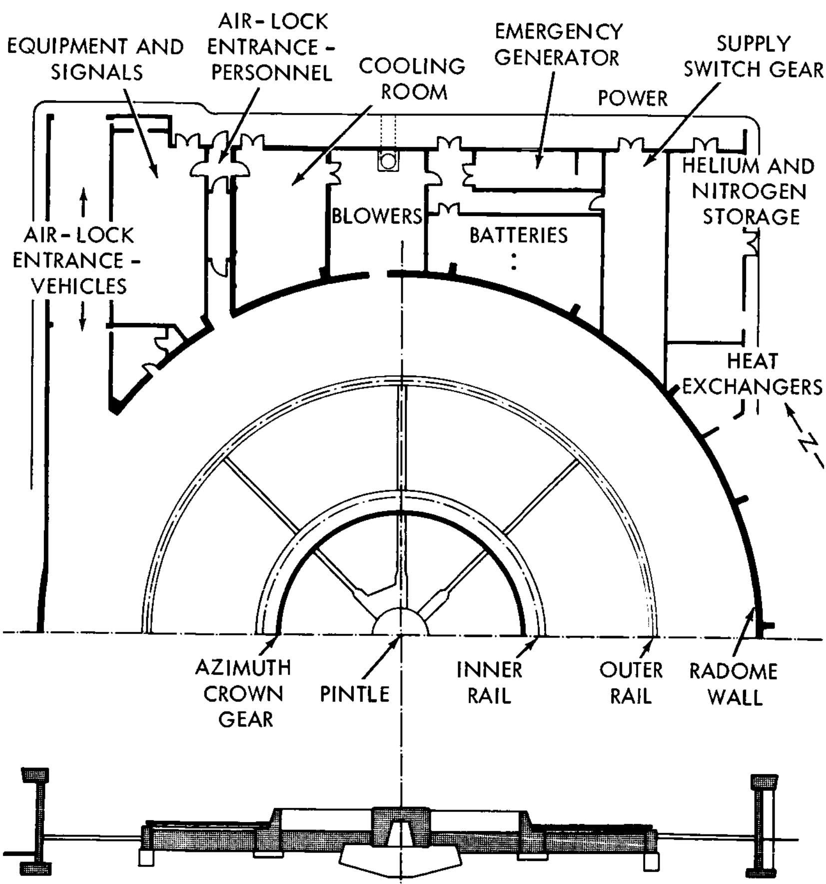


Fig. 5 — The radome foundations (bottom) and floor plan of the radome and its auxiliary building.

Under normal conditions, the radome structure is supported by an air pressure of 3.8 cm of water; with the air pressure raised to 14.00 cm of water, it can resist winds of 160 km per hour.

Radome Auxiliary Building

Entrance air-locks, one for personnel and one for motor vehicles, are located in an auxiliary building of 500 m^2 adjoining the radome. This building also shelters facilities for:

1. The five radome pressurizing blowers and their emergency power supply generator.
2. The switch gear for power supply.
3. Racks for connecting cables to the main building.
4. The refrigeration plant (water is at 4°C).
5. The heat-exchangers for the 8 radome heaters.
6. Storage facilities for liquid helium and nitrogen.

The Main Building

The two tracking antennas, over their respective technical buildings, are supported by concrete piles located on a granite hill which is exceptionally unobstructed. The main building (Figs. 6, 7, and 8) is built at the foot of the antennas, level with the ground; its area is 1500 m^2 (dimensions: 111 $\times$ 14 meters).

The equipment room (340 m^2), the computing center, the two principal facilities, have been specially constructed: a flooring of movable wooden sections with plastic covering is supported at 30 cm from the ground by a metal frame on adjustable screw supports.

The open space beneath the floor is utilized for cables and air-conditioning ducts. The windows do not open. An air conditioning plant, consisting of two refrigerating units of 110,000 calories per hour each, recycles the air in two supply and return systems. One system is for the computation center (16,200 kg/hr of air at 16°C, 62% humidity), the other for the equipment room (35,500 kg/hr of air at 16°C, 73% humidity). The desired environments are respectively: 22°C, 43% humidity and 24°C, 45% humidity

The other facilities within the main power supply building are the 50 cycle station, the switchboard, the batteries, and the LGD (long distance lines) switchboard. There are also facilities for the telephone and teleprinters, a supply store, a conference room, and offices for engineers and administrative services.

Near the main building, a boresight tower 25 m high and especially rigid (motion at the top: less than ± 1.5 mm with winds of 120 km/hr),

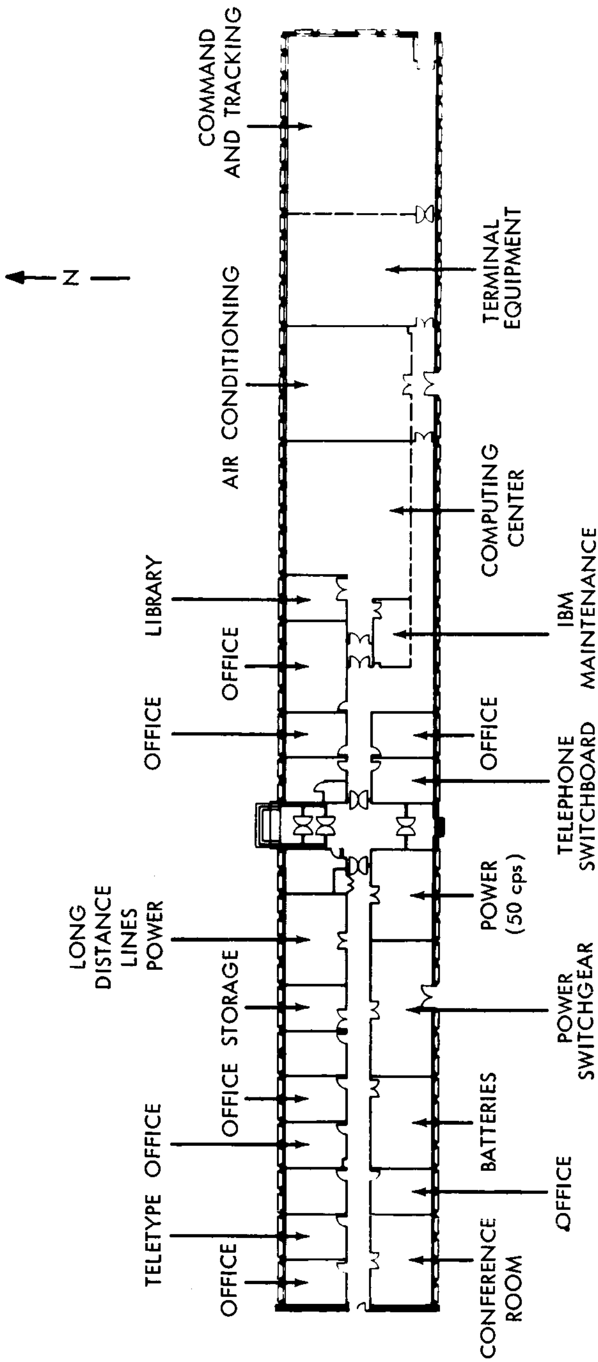


Fig. 6 — Floor plan of the main building.

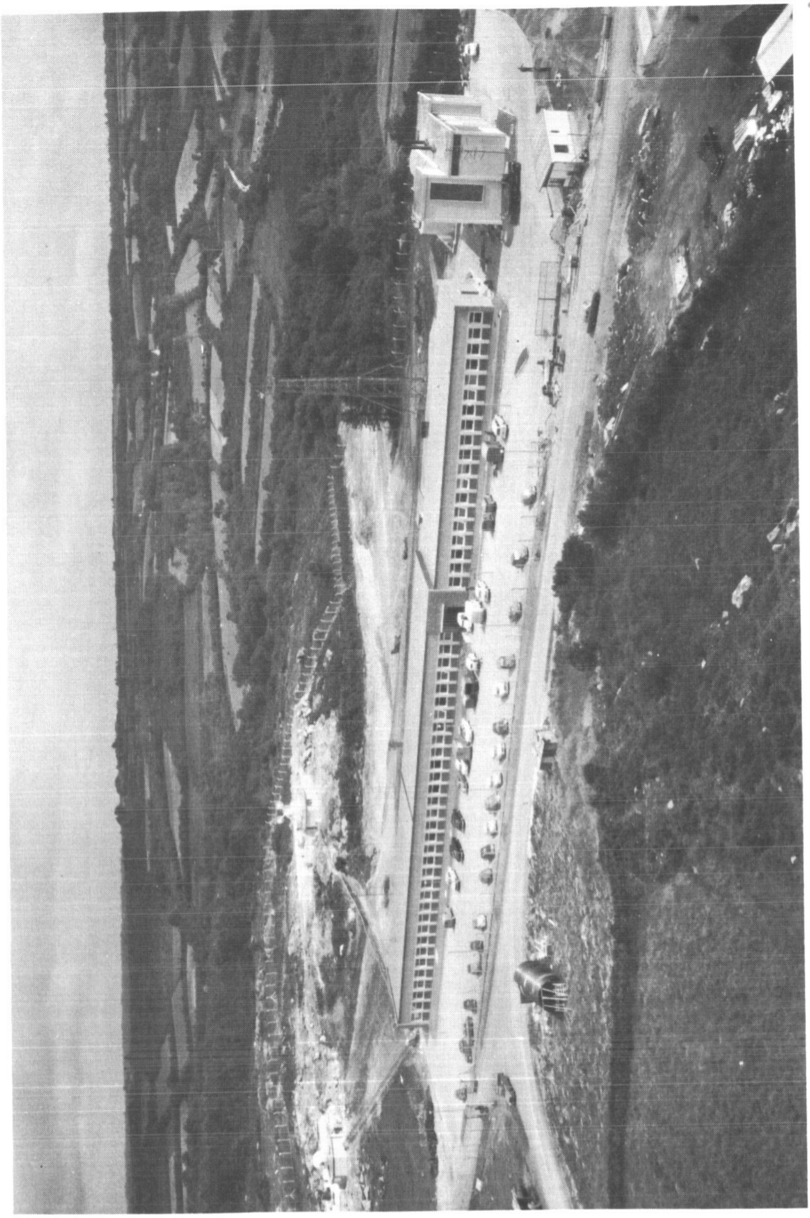


Fig. 7 — The main building area.

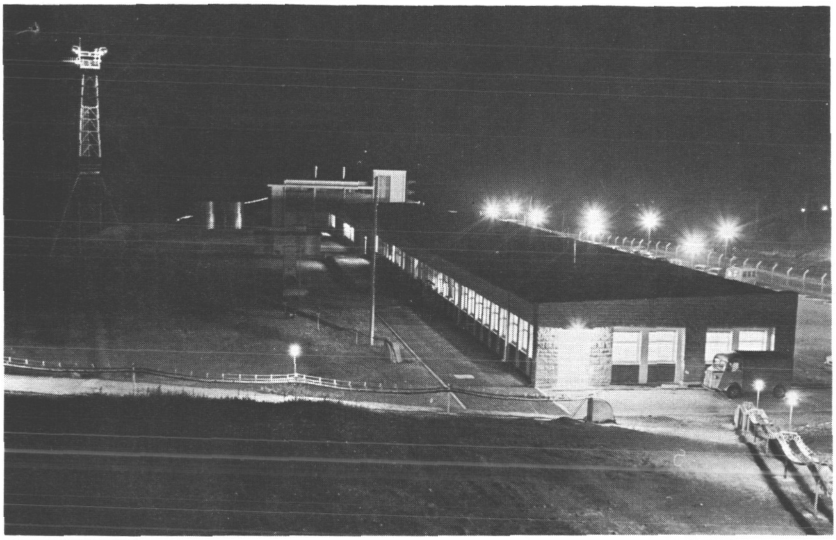


Fig. 8 — View of the main building at night.

supports the antennas which broadcast the signals used for tracking tests, as well as the anemometer which controls the air pressure within the radome.

Three posts support the wire receiving antenna for 18 Mc signals.

The Power Supply Building—The Generators

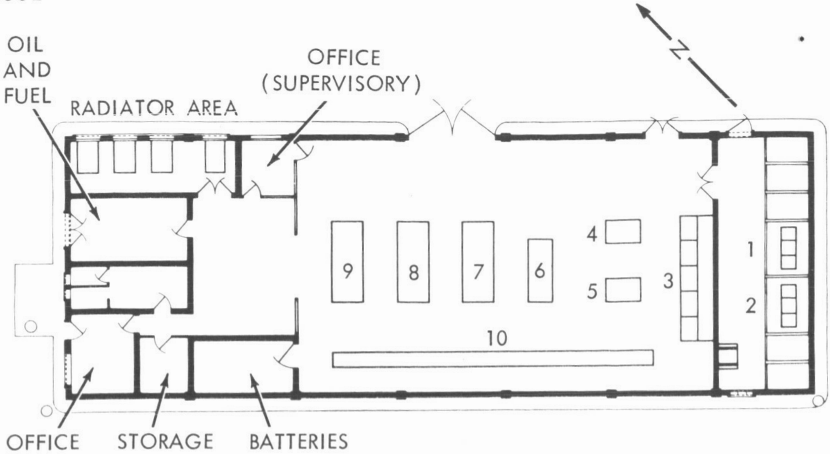
The delivery station receives two power supply lines from the national network.

The dimensions of the power supply building (Figs. 9 and 10) are as follows: length, 35 m; width, 12 m; and height, 5 m. This building houses chiefly a 50-cycle station, 2 50/60-cycle converters, 4 60-cycle generators. For disassembling the motors, there is a 5-ton overhead crane.

Heating Plant

The heating plant, 22 m long, 10 m wide and 6 m high, shelters 2 boilers which supply superheated water, (180°—10 kg/cm^2) which is pumped to the radome heat exchangers through pipes of 125 mm diameter.

The output of 3×10^6 calories per hour is ample to insure proper heating of the radome in winter, and obviates the accumulation of snow or frost. This power may be tripled by the addition of a third boiler.



1, 2	15,000/380 - 220 V - 630 KVA TRANSFORMERS
3	50 cps PANEL
4, 5	50/60 cps CONVERTERS
6	GEI - 60 cps - 75 KVA - EMERGENCY GENERATOR
7, 8, 9	GE2 - GE3 - GE4 - 60 cps - 250 KVA GENERATORS
10	60 cps DISTRIBUTION PANEL

Fig. 9 — Floor plan of the power building.

External Conduits and Cable

External conduits with special compartments connect the different buildings. They are used by medium power, low voltage electric cables;

Fig. 10 — Outside view of the power supply building.

command, communication, and telephone cables; and the water and heating ducts.

Overhead cables connect the tracking antennas to one another and to the main building; they also connect the main building to the test tower (Fig. 11).

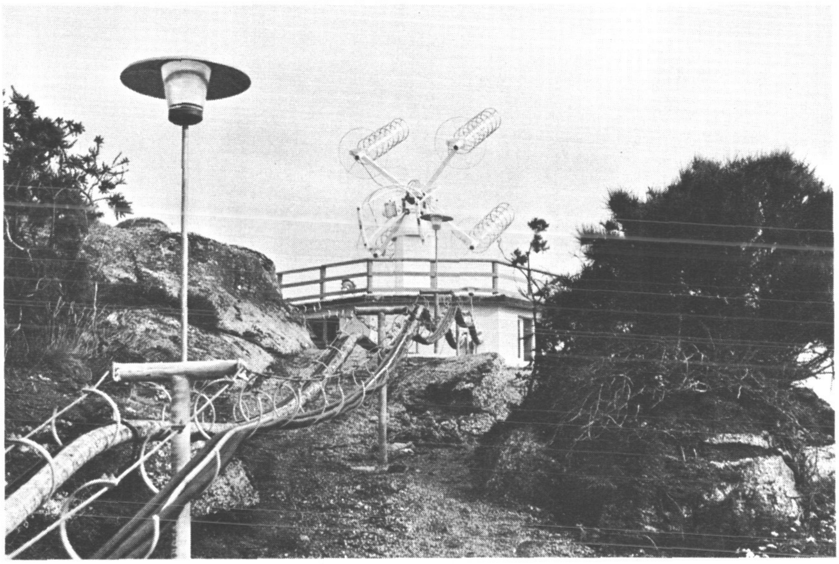


Fig. 11 — Routing of the cables to the command tracker.

Ile Losquet

The satellite simulator (beacon and transponder) is located on a tower 200 m high which is built on a small deserted island 6342 m from the center of the antenna. An elevation of 1.4° is obtained in this way for a beam going from the axis of the horn antenna to the simulator. The tower is very stable; with a wind of 120 km/hr, the motion at the top is less than 0.50 m.

The isolation of the island has necessitated the establishment of a separate power supply. The various equipment are commanded and monitored from the main building by radio.

OPERATIONAL EQUIPMENT

The equipment responsible for the operation of the station will be described in their own location.

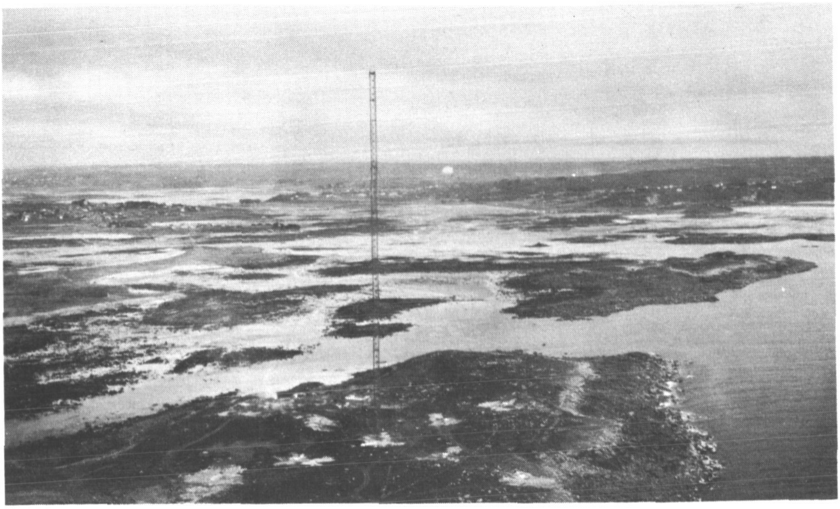


Fig. 12 — View of the Ile Losquet and the 200 m tower.

The Communications Antenna

Located within the radome, the entire structure of the antenna rotates in azimuth on 2 concentric rails (Fig. 13).

The Horn Antenna

This antenna includes a horn-shaped reflector (Fig. 14) which consists of a conical HF horn about 36 m long, a parabolic reflector, the focal point of which coincides with the apex of the cone, and a cylindrical reflector with an opening area of 334 m^2. The antenna is oriented in elevation by rotation about its horizontal axis. Positioning of the antenna is done by means of pinions engaging racks. Vickers hydraulic motors (2 in azimuth and 2 in elevation) drive the pinions.

The Upper Cabin

The antenna throat is enclosed in the upper cabin; a rotary joint insures the connection between the apex and the rest of the horn.

The upper cabin (Fig. 15) contains:

Near the top, the Vernier Auto Track (VAT), the mode coupler and the 4080 Mc receiver.

The communication receiver which changes the 4170 Mc wideband signal into the baseband, the maser and its pump, the cooling

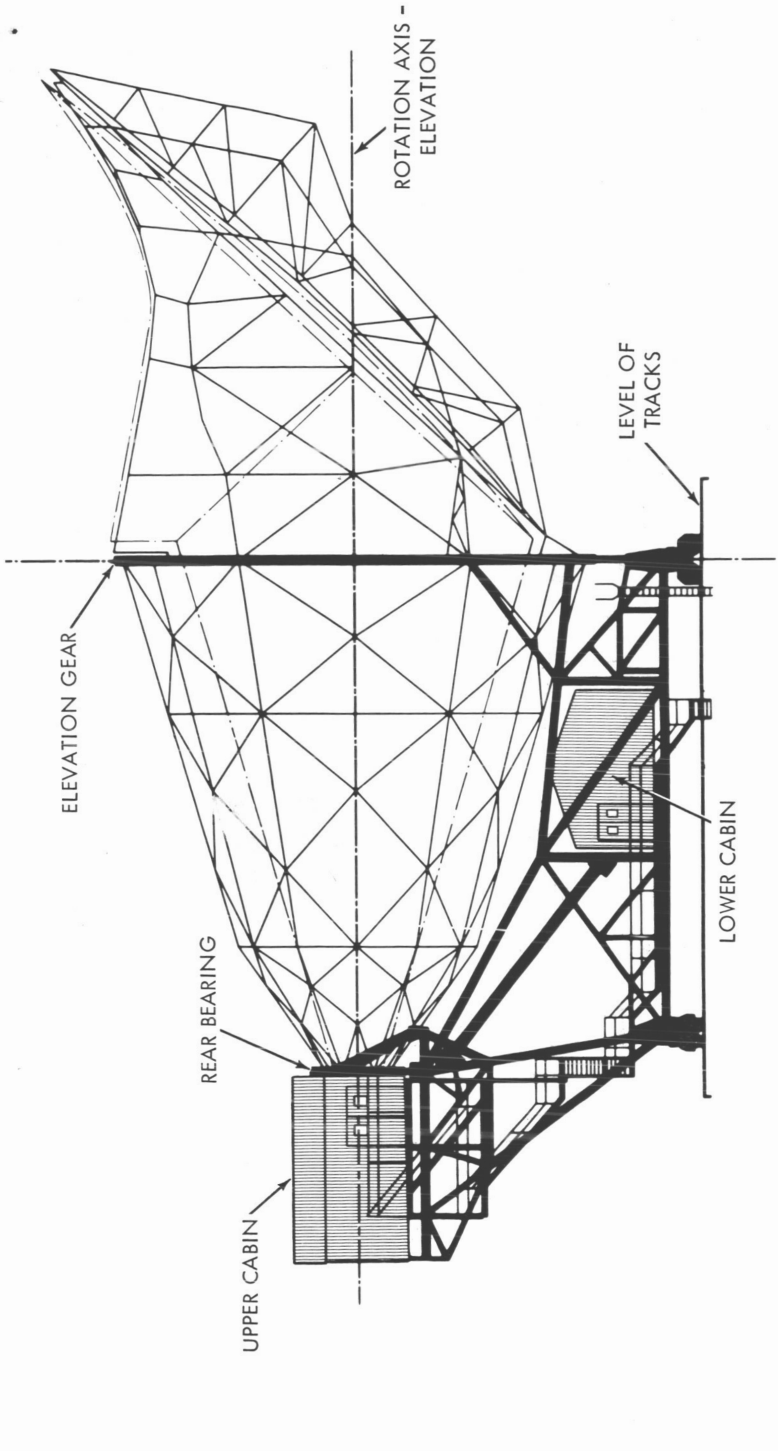


Fig. 13 — Lateral view of the antenna.

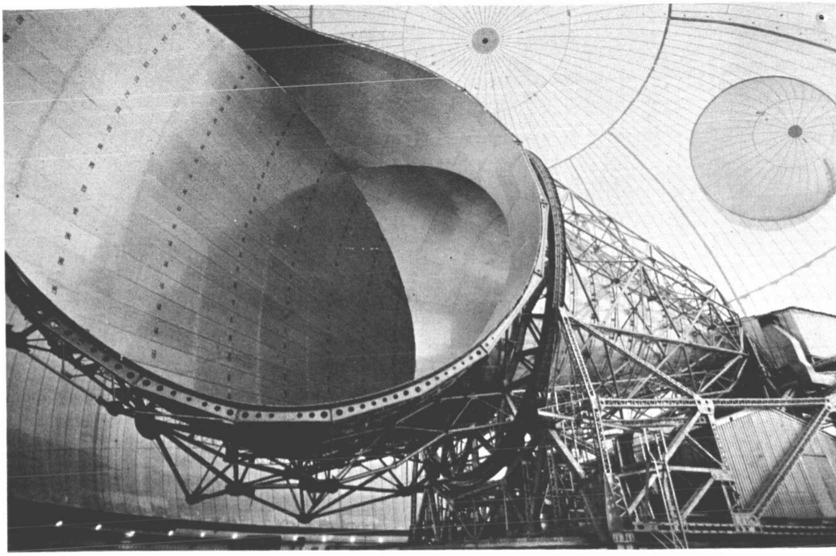


Fig. 14 — The horn reflector.

system using liquid helium and liquid nitrogen, the if amplifier, and the frequency compression loop.

The Telstar transmitter which changes the baseband signal into the 6390 Mc wideband signal, with the power amplifier which has a range of 20 w to 2 kw.

The measurement equipment, radiometric equipment, and antenna drive equipment (coder-resolver—VAT coordinate converter).

The Lower Cabin

The lower cabin contains the antenna steering equipment (Fig. 16):

The X and Y receivers of the Vernier Auto Track equipment.

The antenna control equipment which calculates the error signals.

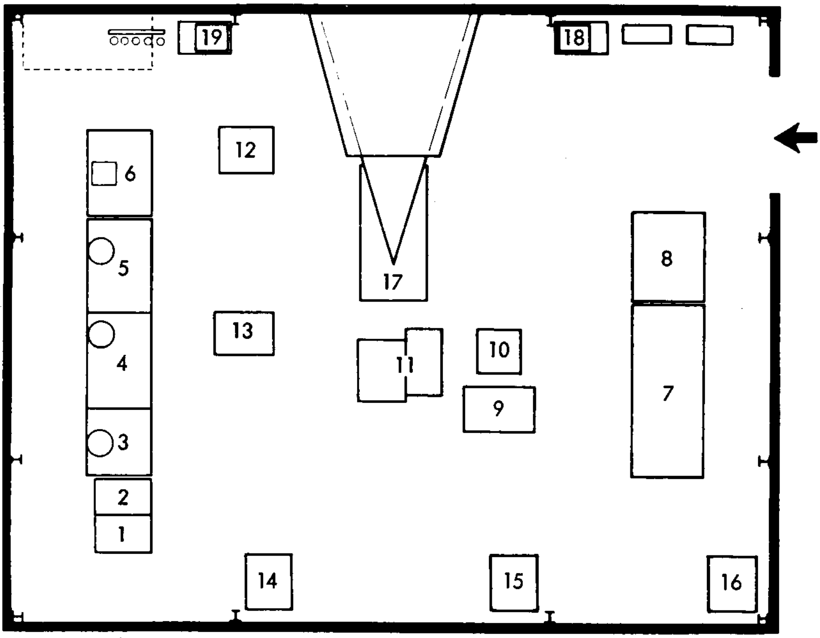
The servo amplifier which drives the hydraulic motors.

The recording and monitoring assemblies.

Also housed in this building: High voltage power for the power amplifier and its stabilizer, the bays for alarm, intercommunication, and multiplex equipment, and the installation for retrieving the helium gas after its evaporation in the maser (Fig. 17).

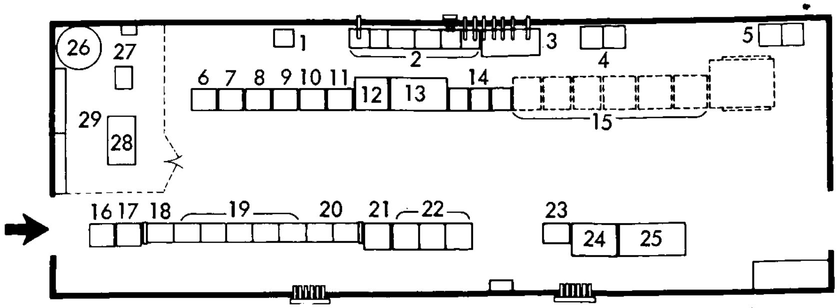
Cables

The radome and the main building are connected by the following cables: 1 cable of six coaxial pairs 1.2/4.4 and 69 sets of four 0.9 wires;



1 LOCAL OSCILLATOR
2 FM GENERATOR
3 HF BAY TRAVELING WAVE TUBE
4 CONTROL AND REGULATION
5 LOW VOLTAGE POWER SUPPLY
6 FM DEVIATOR
7 RECEIVER
8 MISCELLANEOUS EQUIPMENT (RADIOMETRY)
9 MASER HIGH FREQUENCY PUMP
10 MASER
11 LIQUID NITROGEN AND HELIUM STORAGE
12 TRANSMITTER-RECEIVER TESTS
13 FM TERMINAL SET
14 TV TRANSMISSION BAY
15 TV RECEIVER BAY
16 SPARE TRAVELING WAVE TUBE
17 VERNIER AUTOTRACK RF EQUIPMENT
18 RESOLVER ENCODER
19 VAT COORDINATE CONVERTER

Fig. 15 — Floor plan of the upper cabin.



1	420 cps POWER SOURCE
2	ANTENNA DRIVE CONTROL CENTER
3	POWER PANEL
4	RECTIFIERS - 48 V
5	RECTIFIERS - 130 V
6	TEST SIGNAL
7	VAT FREQUENCY
8	VAT ERROR - X AXIS
9	VAT CONTROL
10	VAT ERROR - Y AXIS
11	VAT POWER SUPPLY
12, 13	HIGH VOLTAGE POWER SUPPLY - TELSTAR TRANSMITTER
14	SIGNAL DISTRIBUTION PANEL
15	RELAY TRANSMITTER
16	ANTENNA CONTROL EQUIPMENT - 28 V POWER SUPPLY
17	ANTENNA CONTROL EQUIPMENT - 12 V POWER SUPPLY
18	ANTENNA CONTROL EQUIPMENT - MONITOR GROUP
19	ANTENNA CONTROL GROUP
20	ANTENNA CONTROL TESTING
21	ANTENNA RECORDER GROUP
22	SERVO - MECHANISM - CONTROL
23	INTERCOMMUNICATION
24	CARRIER AND ALARM
25	CARRIER TELEGRAPH CONTROL
26	GAS TANK
27	PURIFIER
28	COMPRESSOR
29	BOTTLES

$\left.\begin{array}{l}\text{27 PURIFIER}\\ \text{28 COMPRESSOR}\\ \text{29 BOTTLES}\end{array}\right\}$ HELIUM RETRIEVAL

Fig. 16 — Floor plan of the lower cabin.

1 cable of 100 pairs 0.9, shielded; and 74 coaxial cables RF 11 A/U. In the radome auxiliary building is a bay for an equalizer-amplifier assembly, and a switching system for television signals.

Fig. 17 — Installation for retrieving helium.

Main Building—Trackers

All controls for the entire assembly are located in the main building as well as the connections with the national telephone and television networks.

Command and Tracking Room

The control console for the station is centered in this room (Fig. 18). All information from the various units converges here; the operations of acquisition and tracking are directed from this point. Three video receivers (2 transmission, 1 reception) are used for monitoring the TV transmission.

The precision tracker consists of:

The frequency acquisition receiver which receives the signals from the antenna.

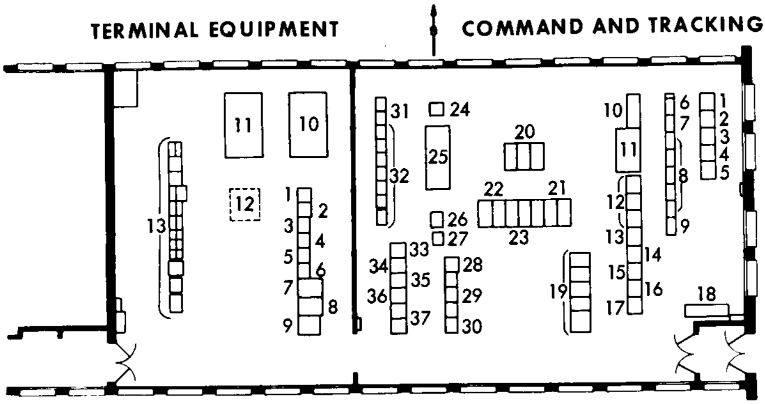
The tracking receiver.

The frequency standard and station clock are regulated by the 18 kc signals from NBA-Panama (crossing duration error 35 ms).

The test generator with 4080 Mc signals.

The track encoder which is also part of the direction system of the horn antenna.

The acquisition tracking equipment will be described in detail in a



COMMAND AND TRACKING

1 CLOCK OSCILLATOR
2 CLOCK POWER SUPPLY
3 TEG - POWER SUPPLY - 250 V
4 TEG - POWER SUPPLY - 12 V
5 TEG - POWER SUPPLY - 28 V
6 CLOCK GROUP
7 TEG TEST GROUP
8 TRACK ENCODER GROUP (TEG)
9 AUXILIARY STATION CONTROL CONSOLE BAY
10 POWER SUPPLY - PRECISION TRACKER
11 PRECISION TRACKER CONSOLE
12 COMBINED FILTERS
13 PRECISION TRACKER LOGIC
14 PRECISION TRACKER RECEIVER
15 PRECISION TRACKER FREQUENCY RECEIVER
16 PRECISION TRACKER FREQUENCY
17 PRECISION TRACKER TEST SIGNAL
18 LINK WITH THE BORESIGHT TOWER (SATELLITE SIMULATOR)
19 POWER PANEL
20 DIRECTOR CONSOLE
21 STATION CONTROL CONSOLE
22 RECORDERS
23 TV RECEIVERS
24 INTERCOM
25,26 CABLE DISTRIBUTION FRAME
27 ALARMS
28 TELEMETRY RECORDER
29 TELEMETRY
30 COMMAND
31 N1 TERMINAL
32 43A CARRIER TELEGRAPH
33 COMMAND TRACKER POWER AMPLIFIERS - AZIMUTH AND ELEVATION SERVOS
34 COMPUTER AMPLIFIERS - AZIMUTH AND ELEVATION SERVOS
35 ELECTRONIC AND MECHANICAL REPEATERS
36 PHASE-LOCK RECEIVER
37 TEST EQUIPMENT

TERMINAL EQUIPMENT

1,2 STILL PICTURE ANALYZERS
3 60 cps MODULE - SYNCHRO-STABILIZATION
4 VIDEO SWITCHING
5 TRANSMISSION MONITOR
6 RECEIVING MONITOR
7,8 MEASURING EQUIPMENT
9 FRENCH TELEVISION NETWORK BAY
10,11 AMPEX VIDEO RECORDER
12 AMPEX FR 100 RECORDER
13 TELEPHONE RACK

Fig. 18 — Command and tracking-terminal equipment rooms.

later section. It provides for telemetry reception and satellite command operations.

Communications with the antenna are handled by a 43 A1 telegraph, N carrier multiplex equipment, permitting a small number of circuits, and therefore, of commutator rings. The radio link to the Ile Losquet tower is handled by special equipment.

Terminal Equipment Room

The terminal equipment provides a link between the communication antenna, the main building and the networks (Fig. 18).

The television rack handles signal distribution and measuring operations (Figs. 19, 20, and 21). Two coaxial cables connect it with the Pleumeur-Bodou microwave link for picture transmission. The telephone lines carry the sound. Two Ampex Videotape magnetic recorders make it possible to record or retransmit the TV signals handled by the station.

The telephone rack will be described in detail in a later chapter. 2 coaxial cables connect it with the Pleumeur-Bodou microwave link.

The above mentioned telephone installation is completed by an Ampex FR 100 8-track recorder.

Fig. 22 shows how the national networks are used for both telephone and television.

Computation Center

The IBM 16 20 computer (see Fig. 23) with its special floating decimal point device, is equipped with a supplementary IBM 16 23 memory. The input and output of large quantities of information is effected by an IBM 16 22 reader card punch.

The computer can be connected to 6 model 729 II high speed tape drives. The use of the tapes is made very flexible by a switching system. Complementary equipment consists of Alphabetic Printing Multiperforator IBM 026, Tabulator IBM 407, and Tape Punch IBM 046.

Service Communications

Three semiduplex machines with tape punches provide for links with

The NASA network, through London,
BTL (Murray Hill), and
The Telex network of France.

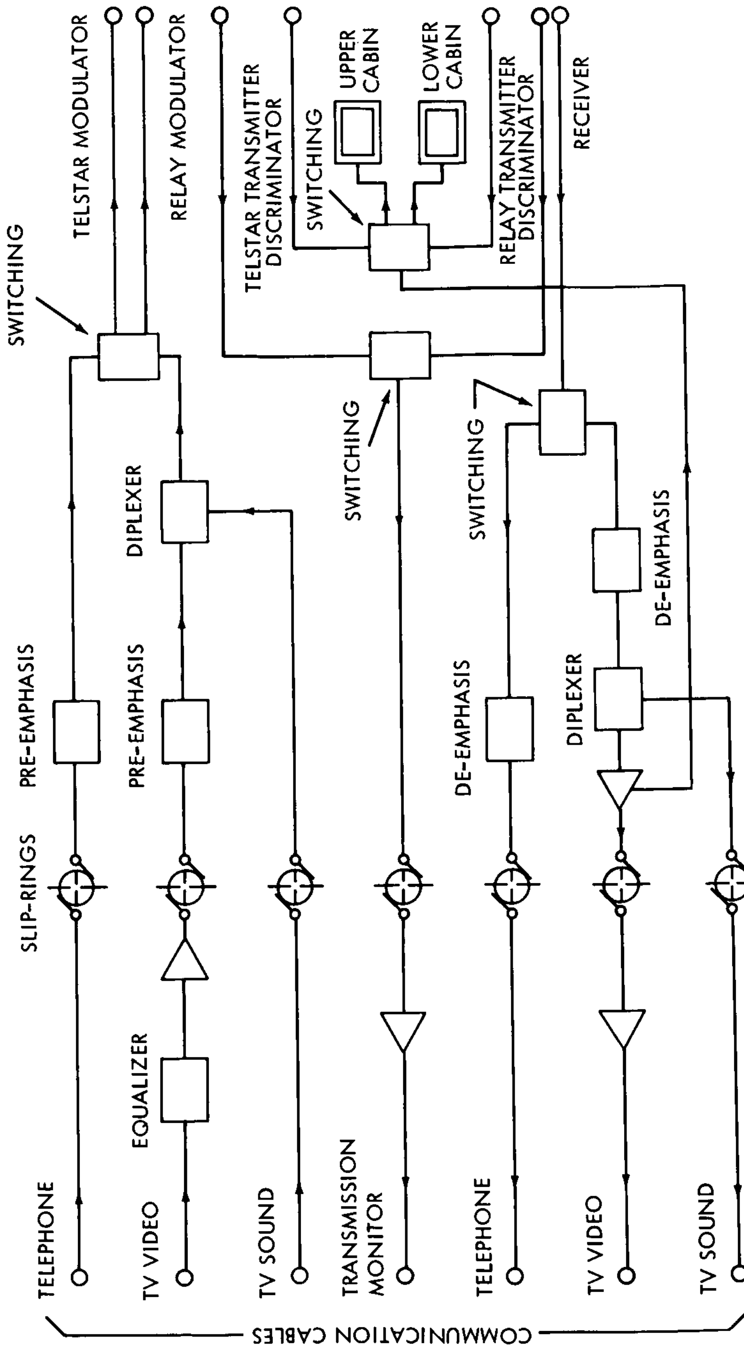


Fig. 19 — Communications between the station and the telephone and television networks.

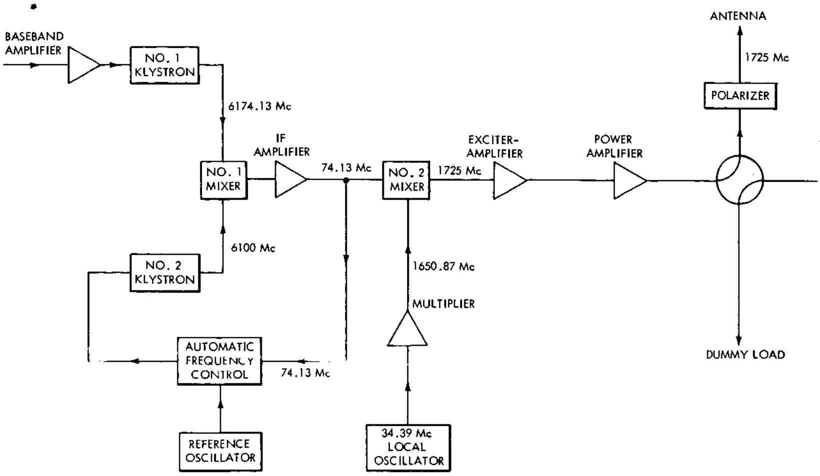


Fig. 20 — Transmission circuits—Functional block diagram.

The telephone switchboard is connected with the French network, and has direct lines to CNET in Paris, NASA at Goddard Space Flight Center, and Andover. An automatic internal system serves the entire station area.

THE COMMAND TRACKER

The command and telemetry assemblies developed by the CNET laboratories perform the following functions:

Acquisition and tracking of the satellite Telstar, using the 136 beacon.

Receiving telemetry data transmitted by the satellite.

Sending of command signals from the station to the satellite.

The equipment chiefly responsible for the performance of these functions is located in or near the main building.

The Antenna and HF Circuits

The antenna (Fig. 24) consists of 4 helicoidal elements (7 coils of 0.50 m in diameter) located on the top side of a square 2.80 m on a side. One side of the square moves in a horizontal plane for the rotation in azimuth, and the other in a vertical plane for the rotation in elevation.

The 3-db beamwidth of the main radiating lobe is 18° at 136 Mc, 22.5° at 123 Mc (Fig. 25).

Fig. 21 — View of the television bay.

If the signals received by each helix are called A, B, C, D (Fig. 26), in a monopulse system of three $6\lambda/4$ phase loops, the following signals are developed.

$A + B - (C + D)$ elevation error signal
$A + D - (B + C)$ azimuth error signal
$A + B + C + D$ reference sum signal

Each signal is directed toward the corresponding preamplifier, through a passband filter of 5 cavities, centered on 136.5 Mc, with a 3-db bandwidth of 2 Mc and attenuation of about 80 db at ± 10 Mc. The insertion loss is less than 3 db.

Upstream of this filter, in the path of the reference signal, a directional coupler is inserted which permits the injection of command transmission at 123 Mc. Thanks to the 130 Mc filters, the preamplifiers

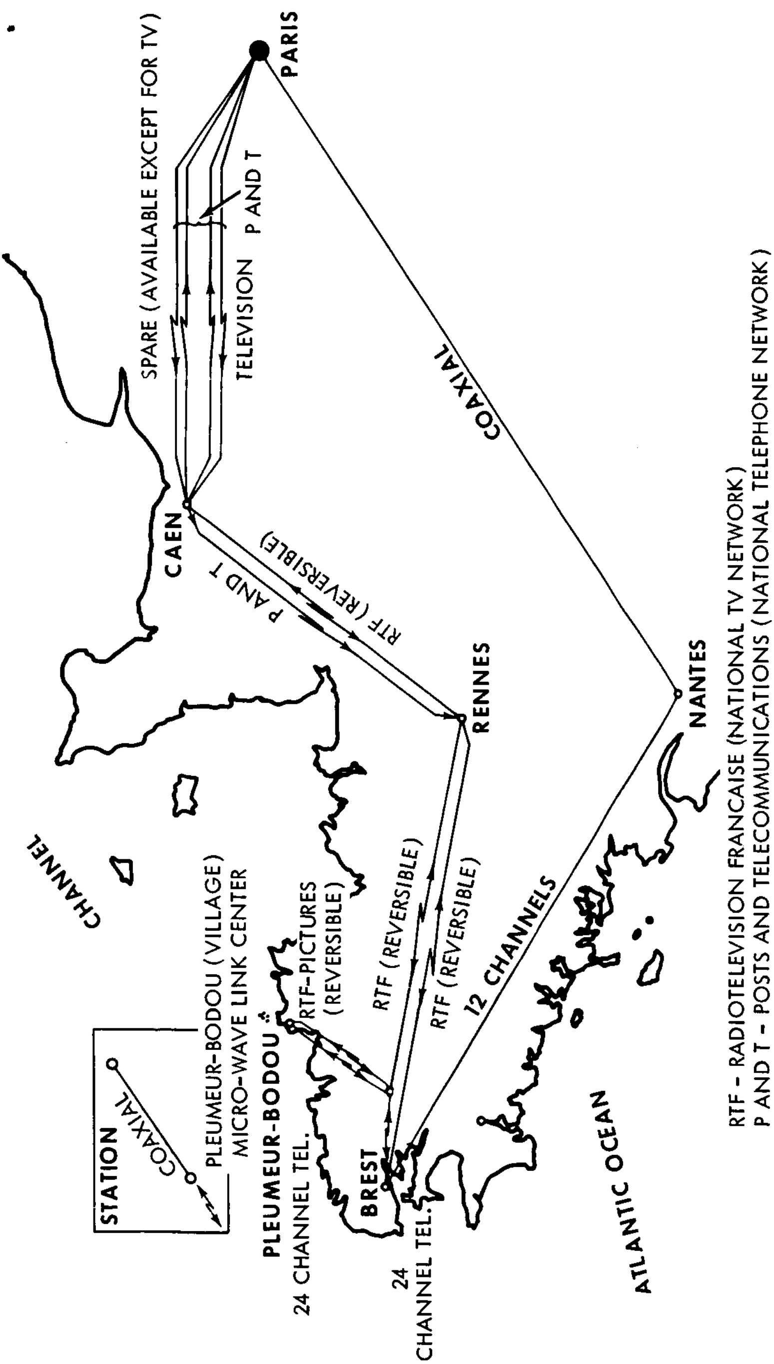
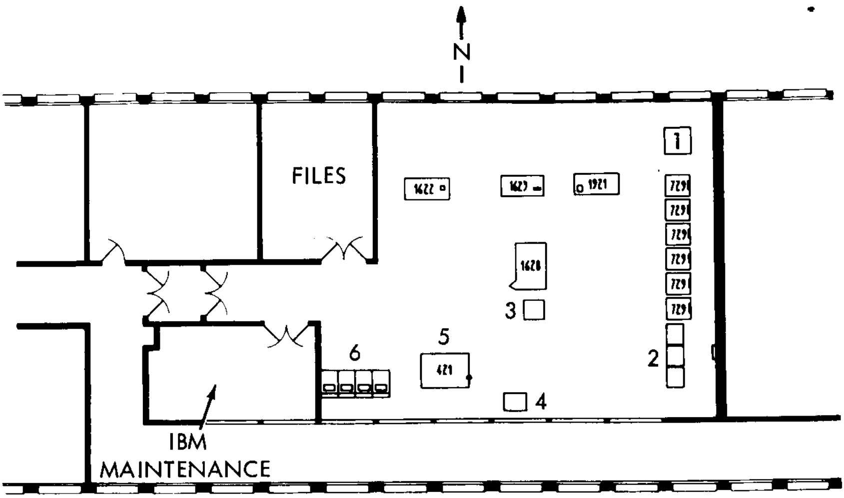


Fig. 22 — Television terminal equipment interconnections.



1 IBM 046 UNIT
2 TAPE SWITCHING UNIT
3 TAPE SWITCHING CONSOLE
4 IMB 026 UNIT
5 TABULATOR - IBM 421 OR 407
6 POWER DISTRIBUTION PANEL

Fig. 23 — Floor plan of the computation center.

present a very high impedance for the command signal which is radiated in its entirety by the 4 antennas in parallel.

The preamplifiers located at the base of the antenna, as near as possible to the monopulse system, are fed and controlled from the main building. The signal is amplified in one stage at 136 Mc, then converted to a first if of 20.25 Mc. The local oscillator is the same for the 3 preamps; it is situated in the main building. Its frequency is transmitted and multiplied inside the preamps. The overall noise factor is below 2 db.

The Receiver

The receiver (Fig. 27), situated in the main building, is composed of 3 chains which are quite distinct, but as similar as possible. The 20.25 Mc signals from the preamps are amplified, converted to 500 kc, amplified again and detected. The reference signal is used to drive a phase-coherent loop which determines the frequency of the local

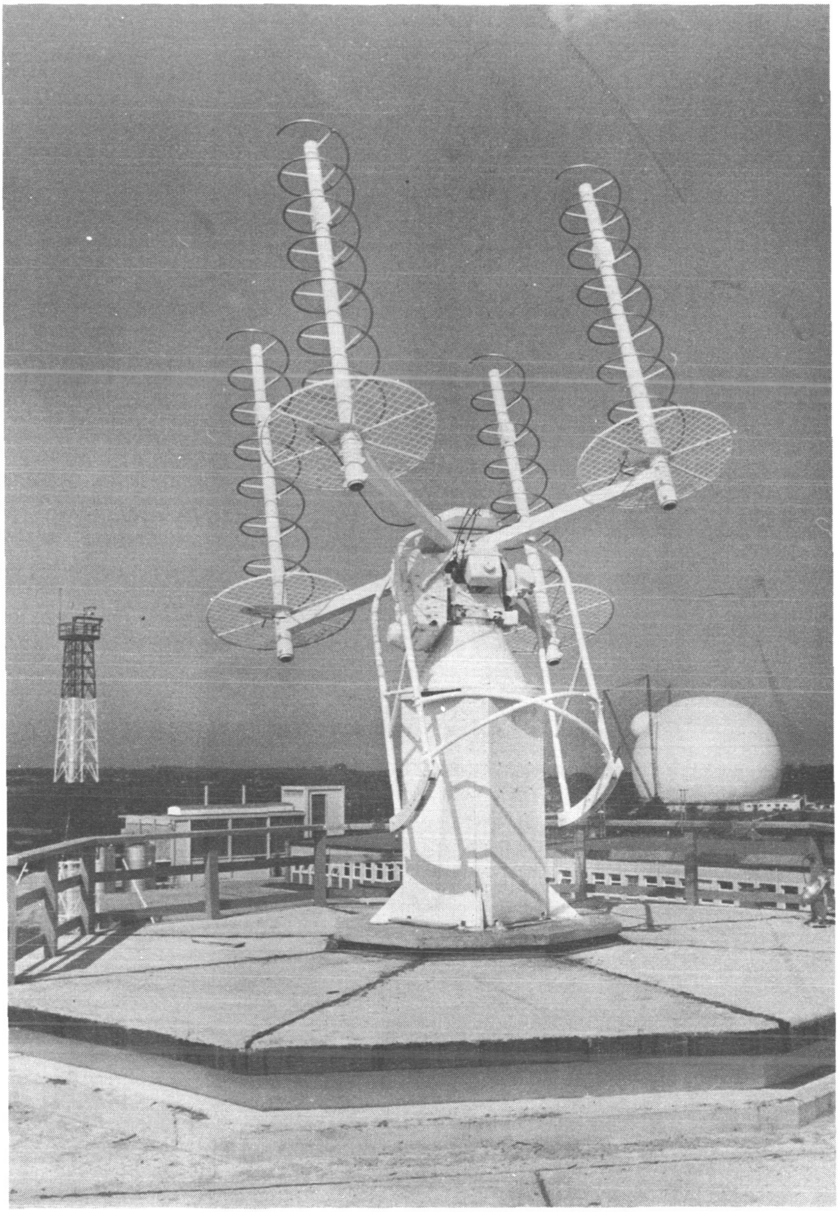


Fig. 24 — The command tracker antenna.

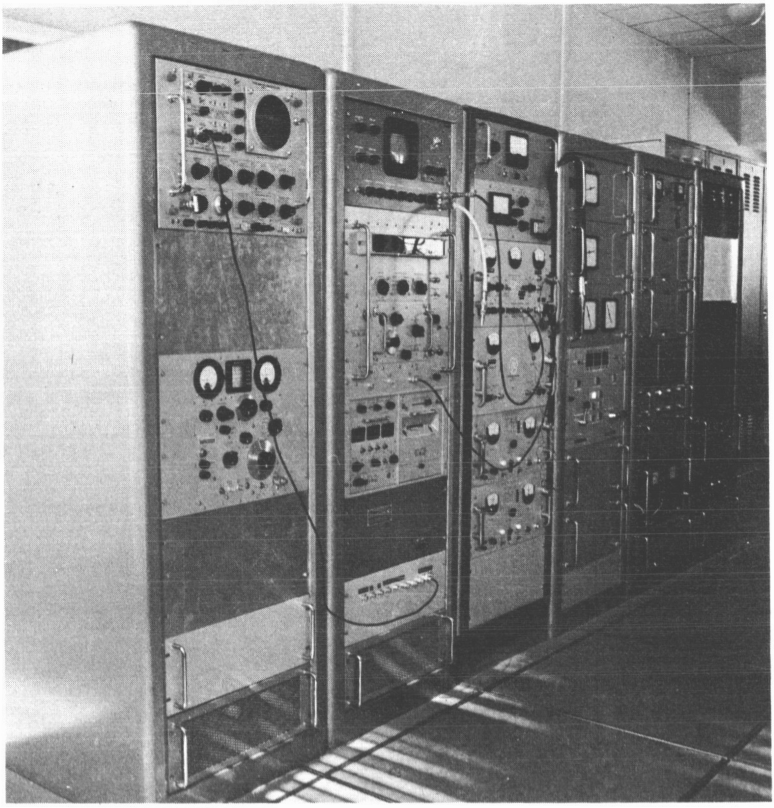


Fig. 25 — View of the command tracker cabinets.

oscillator, which, after various multiplications, is used for all frequency changes. In 3 synchronous detectors fed by the local reference oscillator, a signal proportional to the level of the received signal is developed and sent to the automatic gain control circuits of the 3 channels, and two error signals, suitably filtered and amplified, are sent to the antenna servomechanism.

The receiver's principal characteristics are:

Variation of the output level as a function of the input level.

Efficiency of the AGC: 0 db from −130 dbm to −80 dbm
10 db from −150 dbm to −125 dbm

Difference in gain between the three amplification chains, less than 1 db.

Phase drive as a function of the input level in each chain.

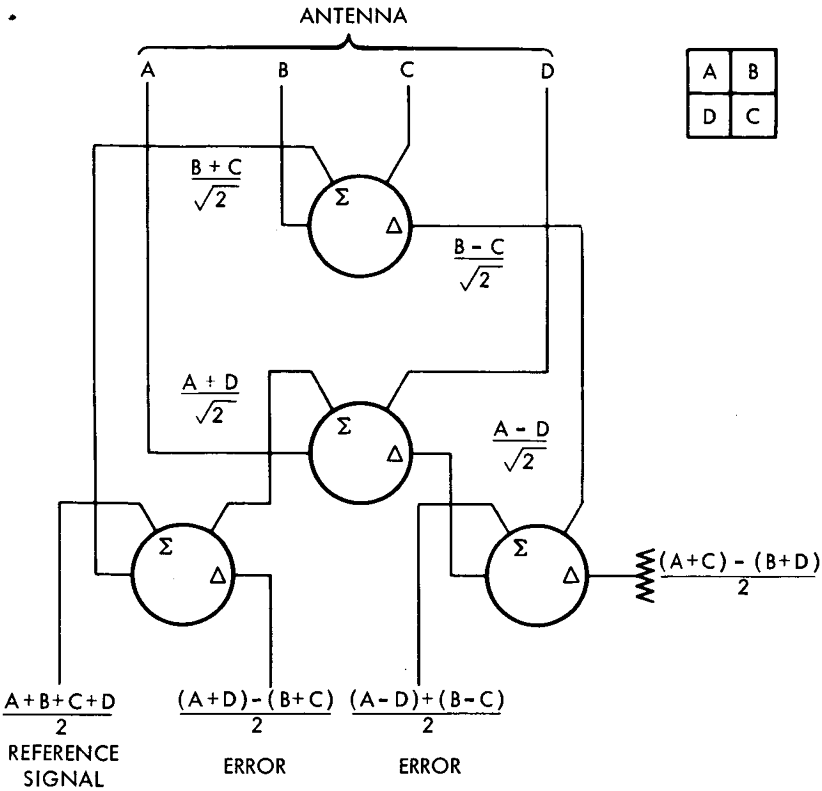


Fig. 26 — The command tracker monopulse system.

0° from −125 dbm to −80 dbm.
3° from −150 dbm to −125 dbm.

Differences between the phase errors introduced by the 3 chains: less than 4°.

Passband of the receiver: adjustable from 10 cycles to 1 Mc.

Servomechanism

The error voltages are led to the two servo drive chains in elevation and azimuth.

The modes of operation (Fig. 28) are as follows:

Waiting: voltage is applied to the drive, but the power amplifier is grounded and the antenna is free.

Manual: the antenna can be oriented in any direction by two manual controls.

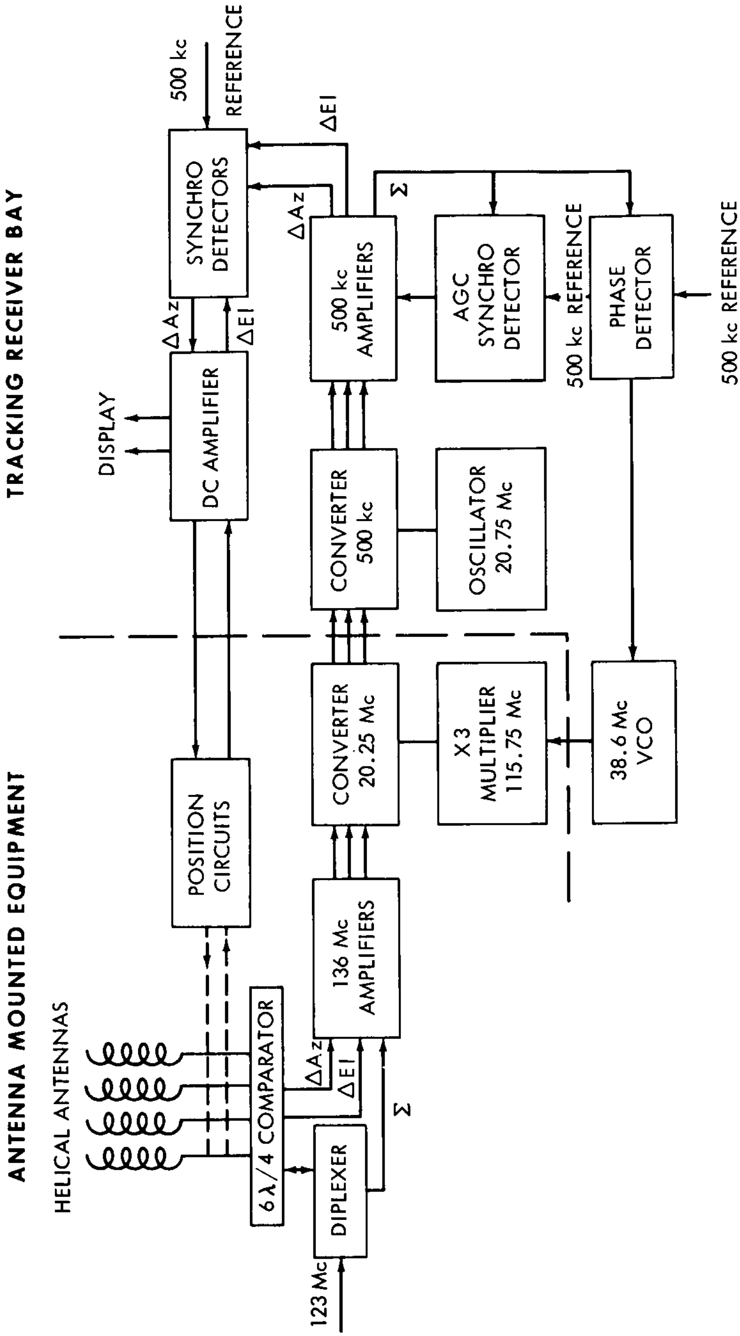


Fig. 27 — Schematic diagram of the command tracker.

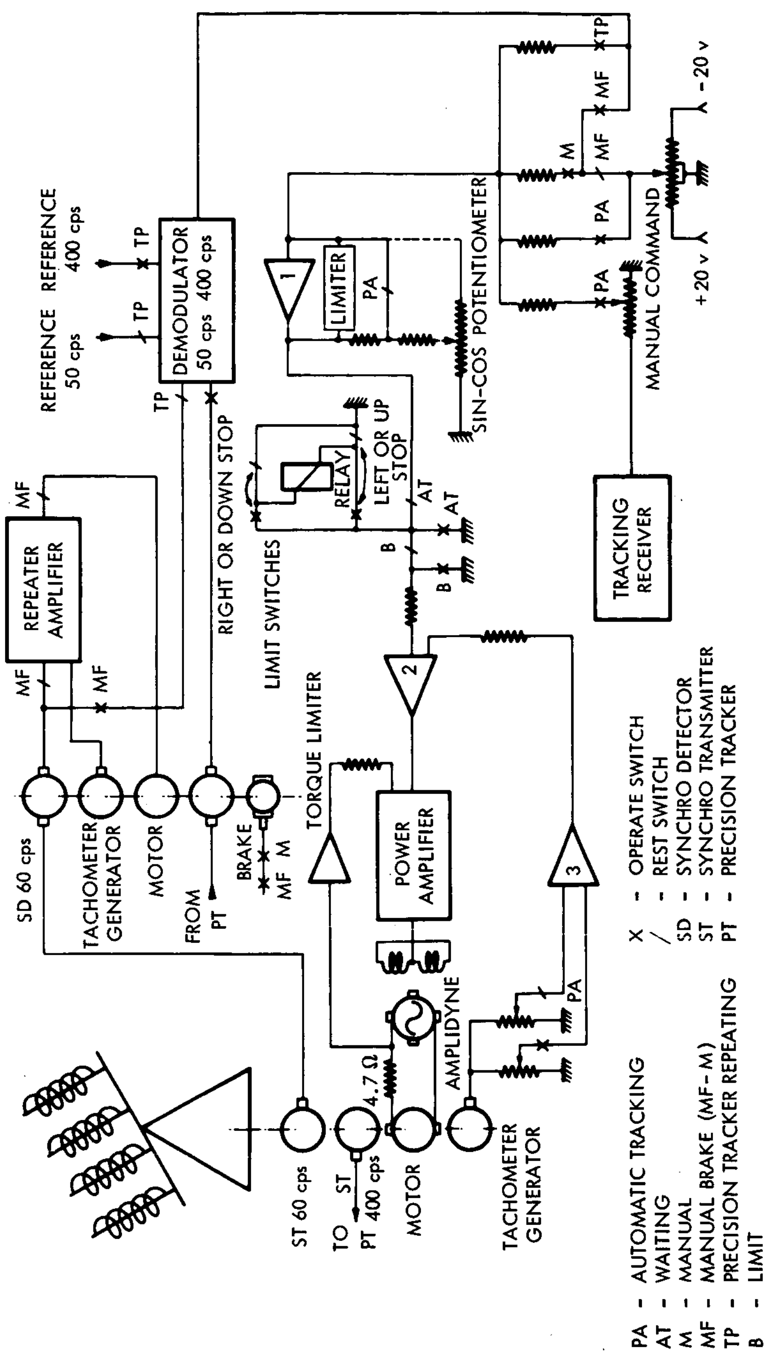


Fig. 28 — Schematic diagram of the command tracker servo-mechanism.

When these controls are stopped, the antenna is commanded to hold its position by means of a repeating mechanism which can be locked in position; this is the position of waiting for the satellite.

Autotrack: the servo drive is connected to the tracking receiver which supplies it with the error voltages.

Slaved to the precision tracker antenna: In this mode in particular, the antenna can be driven by program through the precision tracker.

Conversely, in the acquisition phase, if no correct program is available, the precision tracker can be slaved and pointed toward the satellite by the command tracker.

Various synchro-transmitting and synchro-receiving devices give the antenna position and display elevation and azimuth angles with an accuracy of 1/10°.

Telemetry

The telemetry data transmitted by the 136 Mc carrier of the satellite are received and recorded.

The binary groups frequency modulate a 3-kc subcarrier.

This subcarrier is extracted from the 136 Mc by a synchronous demodulator, after which it can be recorded directly on a FR 1100 tape recorder. It can also be processed by a phase-lock discriminator which extracts the telemetry pulses. After being reshaped, the pulses are transmitted by telephone circuit to the CNET laboratories in Paris, where they are reduced.

The Encoder and the Command Transmitter

Commands to the satellite can be generated either by the encoder or by the station control console.

In the encoder circuitry, each command is transformed into a sequence consisting of a digital group repeated five times and followed by three "silent" groups. The entire sequence provides all-or-nothing modulation to the 5.45 kc subcarrier produced by a crystal oscillator. The oscillator frequency is also used as a reference for the generation of groups and of pulses modulated in duration. The subcarrier in turn modulates the 123-Mc transmitter.

TELEPHONE TERMINAL EQUIPMENT

Communications

The telephone terminals serve the following communication lines:

60 circuits between Pleumeur-Bodou and Andover via the Satellite.

12 circuits Pleumeur-Bodou—Brest.

12 circuits Pleumeur-Bodou—Paris via Brest.

These circuits use the Pleumeur-Bodou (village)—Brest microwave link.

Between the main building and the radome, the 60 Andover circuits utilize 2 of the coaxial pairs from the 6-pair cable; 3 other pairs are used for television picture transmission, the sound using one four wires set.

The connection to the microwave station of Pleumeur-Bodou by the two coaxial autocarrier cables, together with the microwave link, can support the operation of the 60 circuits.

Instruments

The telephone equipment consists of the items listed below and is mounted on racks assembled into a bay (Fig. 29).

The Pleumeur-Bodou—Andover Circuits are (Fig. 30):

5 systems of 12 channels forming 5 primary B groups (60-108 kc) connected to the distributor in primary groups.

5 primary group modulator-demodulators (GP 1, 2, 3, 4, 5) connected on the 60-108 kc side to the primary group distributor, and on the other side, after coupling, to the secondary group distributor, form in this way a basic secondary group (312-552 kc).

4 primary group modulator-demodulators (GP 2, 3, 4, 5) connected on the 60-108 kc side to the primary group distributor, and connected separately on the other side to the secondary group distributor.

5 secondary group modulator-demodulators (GS 2, 4, 6, 8, 11) which, connected on the 312-552 Mc side to the secondary groups repartitor, terminate after coupling at the transmitting and receiving amplifiers.

A transmitter amplifier and a receiver amplifier, each equipped with an equalizer and an artificial line, compensating the attenuation of the coaxial pairs in both directions, and at all frequencies in the band between 12 kc and 13 Mc. In the upper cabin the coaxial pairs are directly connected, one to the modulator (transmission) and the other to the demodulator (receiving).

A 120 kc primary group modulator-demodulator, a coupler and amplifiers make it possible to take this group from the distributor and to use it either in the 60-108 kc or the 12-60 kc positions.

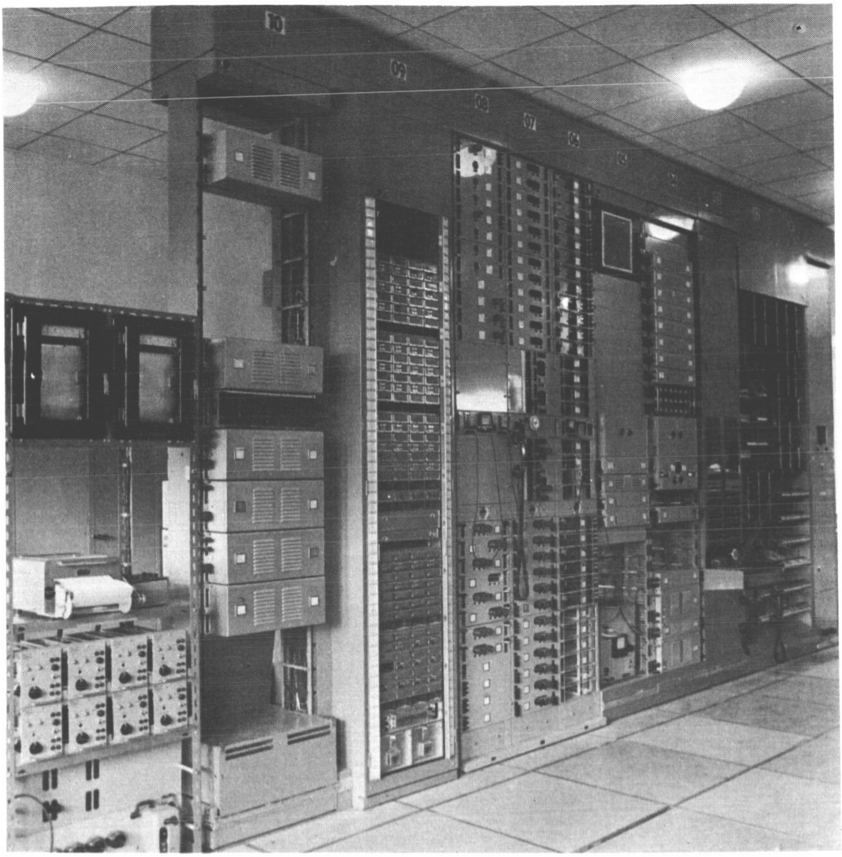


Fig. 29 — View of the telephone terminal equipment.

Both primary and secondary group distributors are equipped with jacks, so that with patch cords quick access is available to the following combinations:

60 circuits occupying one of the following frequency-bands:

312-552 kc	secondary group 2
812-1052 kc	secondary group 4
1308-1548 kc	secondary group 6
1804-2044 kc	secondary group 8
2548-2788 kc	secondary group 11

60 circuits divided into 5 groups of 12 (5 primary groups) each of these groups being situated in one of the above mentioned secondary groups.

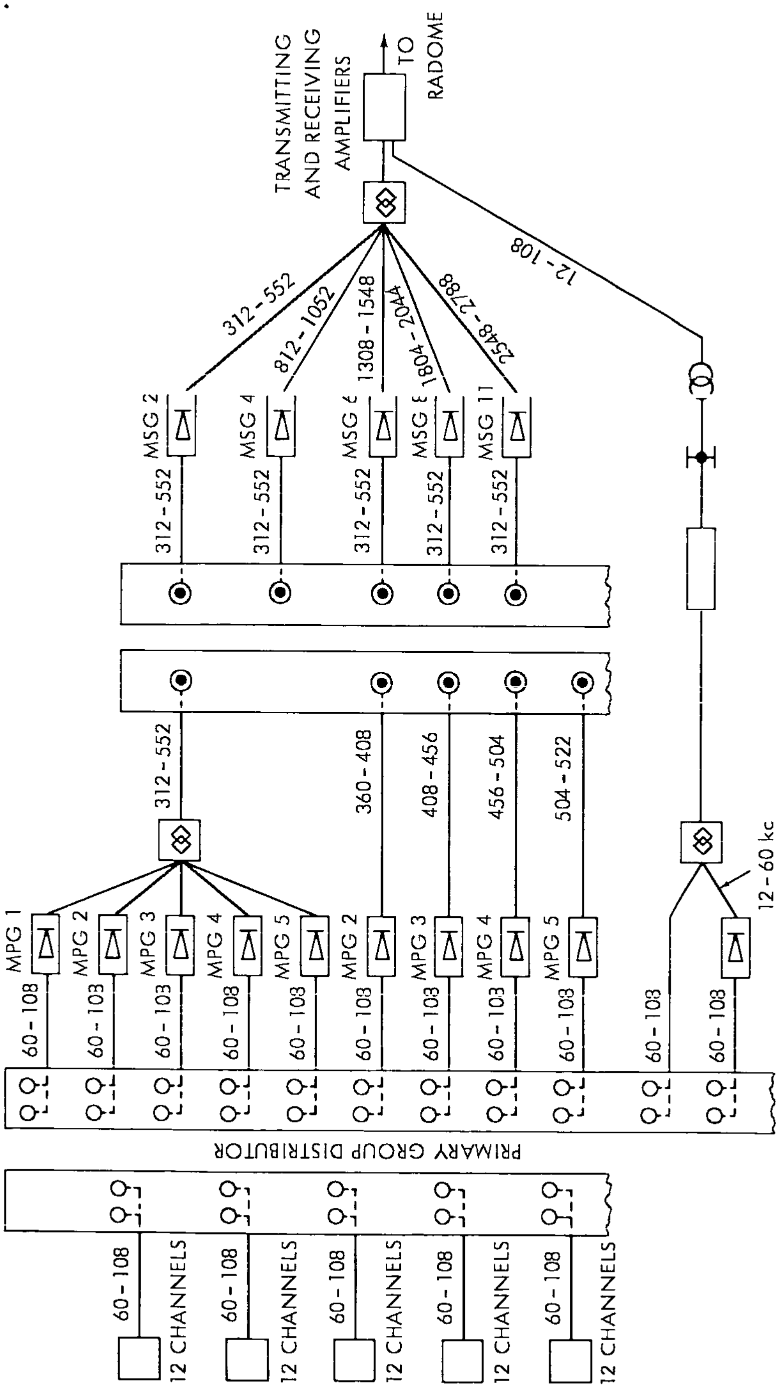


Fig. 30 — Telephone equipment—Functional diagram.

or, 12 circuits occupying either the 12-60 kc band or the 60-108 kc band.

The Brest Pleumeur-Bodou Circuits (Fig. 30) are:

2 systems of 12 channels each, constituting 2 base B primary groups.

2 primary group modulator-demodulators (GP 4 and 5) which place these two groups of 12 channels in the 456-504 and 504-552 kc bands.

A transmission modulator and a receiver amplifier together with equalizers and artificial lines. This assembly compensates the attenuation of the overhead coaxial pairs in both directions, and at all frequencies between 60 and 300 kc.

Twelve of these 24 channels constitute the Pleumeur-Bodou- Brest circuits; the other 12 go on to Paris as a primary group. Channels 4, 5, and 6 of these last group can be used either separately as telephone lines or together as the "sound" circuit for TV. For this purpose, these three channels are switched in Paris and Pleumeur-Bodou to special equipment which provides a circuit with a pass band of 30 to 10,000 cps.

The components of the equipment for these 24 circuits are connected to the various distributors in normal fashion, with no provision for rapid changeovers. However, the 12 Paris channels as well as the satellite transmission channels go through a patchboard where they are hooked up in such a way as to be easily connected on 4 wires, thus making Paris-Andover circuits.

General Equipment

There are: a central generator; generators for the primary group carriers; generators for the secondary group carriers; and generators and transmitters for the 60 and 30 kc pilot signals.

All the telephone equipment parts are standard, but their configuration has been planned in a special way to accommodate the necessary measurements and transmission tests (Fig. 30).

BORESIGHT TOWER EQUIPMENT

Equipment which simulates all the essential functions of the satellite has been placed on top of the 200 m tower built on the Ile Losquet: a beacon with an unmodulated 4080 Mc signal and a transponder which receives the 6390 Mc signal of the horn antenna; the 6390 Mc signal is transmitted at 4170 Mc.

The problems presented to the CNET laboratories in the building of this equipment were very different from those encountered by the developers of Telstar. There were no serious limitations as to weight, size, or power supply to be considered; the environment, however, called for protection against rain, dampness and salt air. This was achieved by cases of lightweight alloys, and rubber-sealed joints.

On the other hand, the equipment being approximately 1000 times closer to the antenna than the satellite, its signals had to be a million times weaker than those of the satellite; also, the signals received by the transponder are a million times stronger and it must transmit less power than it receives.

The Beacon

The beacon (Figs. 31, 32, and 33) was designed entirely with semiconductors, whence its highly dependable operation. A two-stage multiplier, the two stages of which are separated by amplifiers, is driven by a crystal oscillator with a resonance frequency of approximately 50 Mc. This assembly is located within a thermally insulated area for greater stability.

A solid-state generator of high harmonics produces the 4080 Mc signal. A parabolic antenna (Diam: 60 cm), fed at its focus by a small plane reflector, directs the 4080 Mc signal toward the radome. The circularly polarized signal is brought to this point by a circular waveguide filled with dielectric.

To simulate a Doppler effect (± 140 kc in 10 minutes) the frequency of the oscillator can be varied continuously over a range of about ± 2 kc by means of a semiconductor diode with variable capacitance. The command voltage is obtained by a remotely controlled motor. A high frequency attenuator controls the beacon output level (-50 dbm to -70 dbm). The stability for 1 minute is better than 10^{-7}.

Repeater

It was possible to simplify the repeater very much because the signals going through it require no amplification. The frequency is simply changed by a semiconductor diode (Fig. 34). The transposition frequency of 2220 Mc is a harmonic amplified by electronic tubes of the same resonant frequency as a crystal oscillator. The passband is very wide, ± 25 Mc, and a wideband filter provides that only the 4170 Mc signal is sent to the antenna, which are helical (Fig. 35). The insertion gain between omnidirectional antennas is -11.6 db, and can be adjusted by means of a variable attenuator.

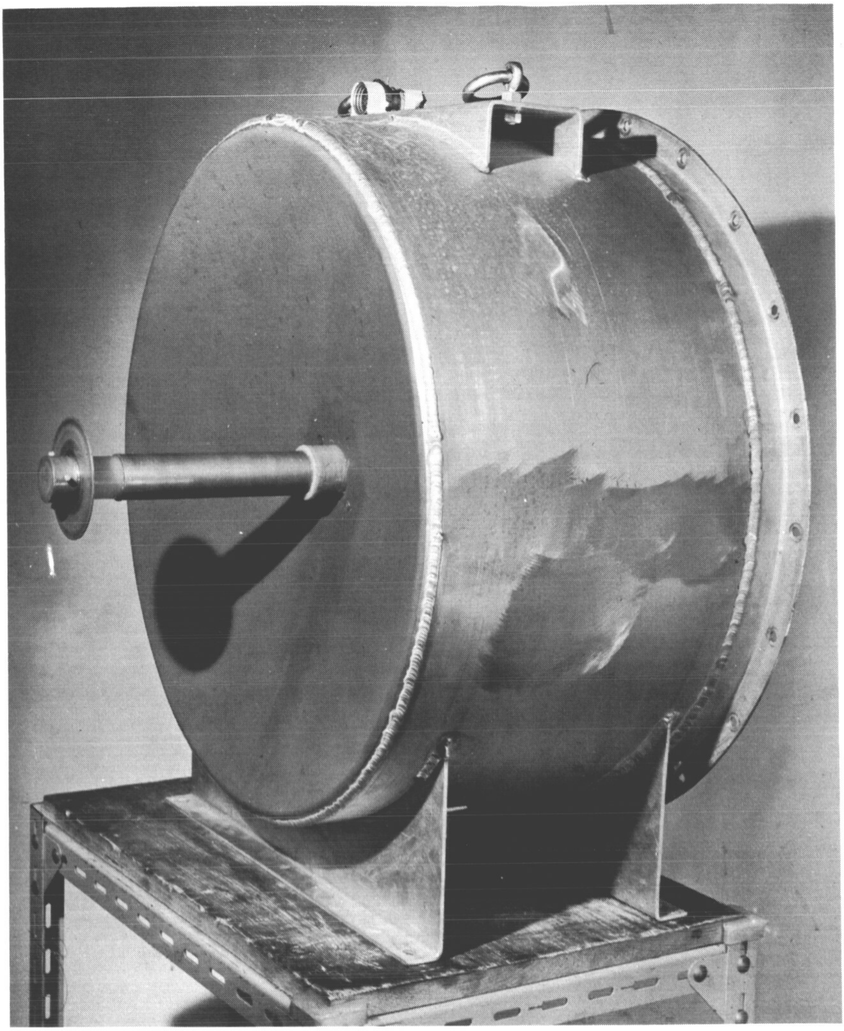


Fig. 31 — View of the Telstar Simulator 4080 Mc Beacon.

For a 2-kw transmitted power of the horn antenna the received signal level is —0.8 dbm, and the transmitted power is —12.4 dbm. The power level at the horn antenna input is —133.4 dbm.

ELECTRICAL POWER

The electrical power equipment is distributed in the various areas and buildings already described (Fig. 36).

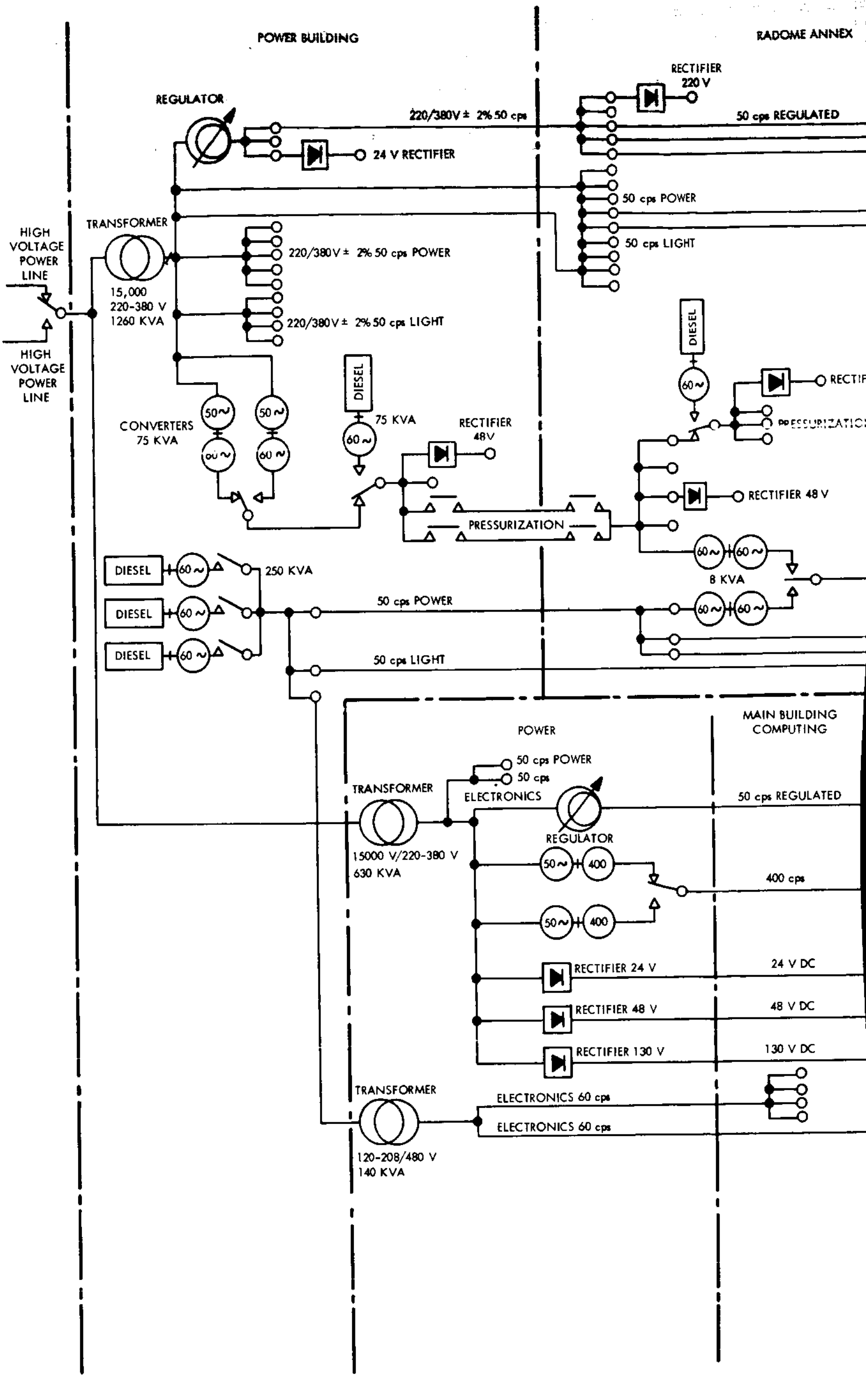
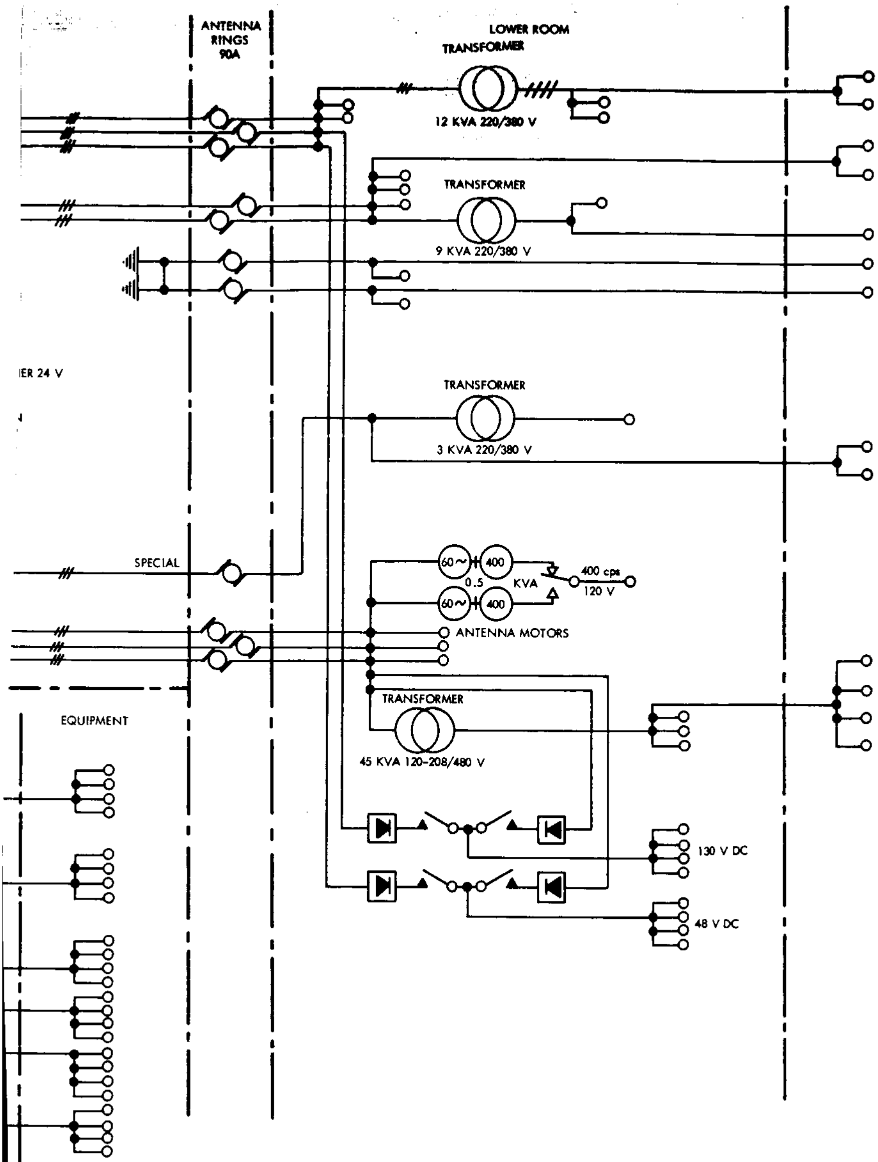


Fig. 36 — The electrical install



tion—General diagram.

3

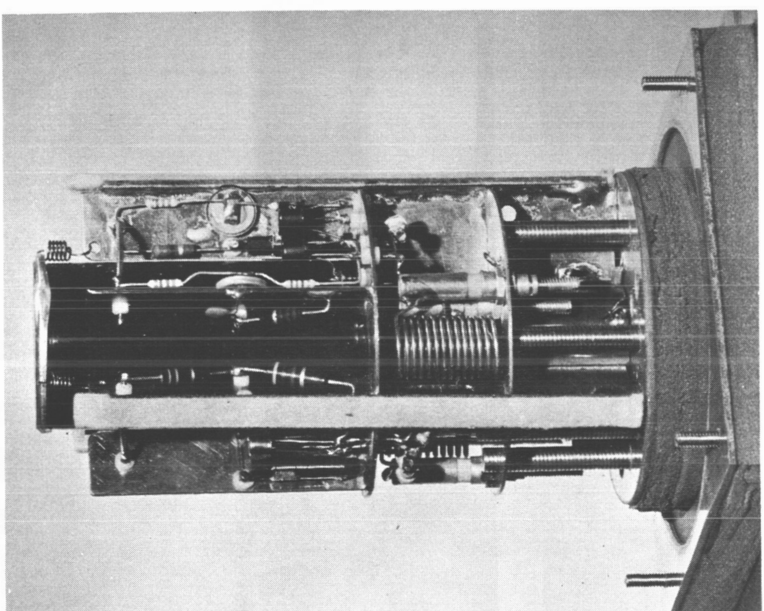


Fig. 32 — View of the thermostatic controlled oscillator providing 200 Mc to the simulator beacon.

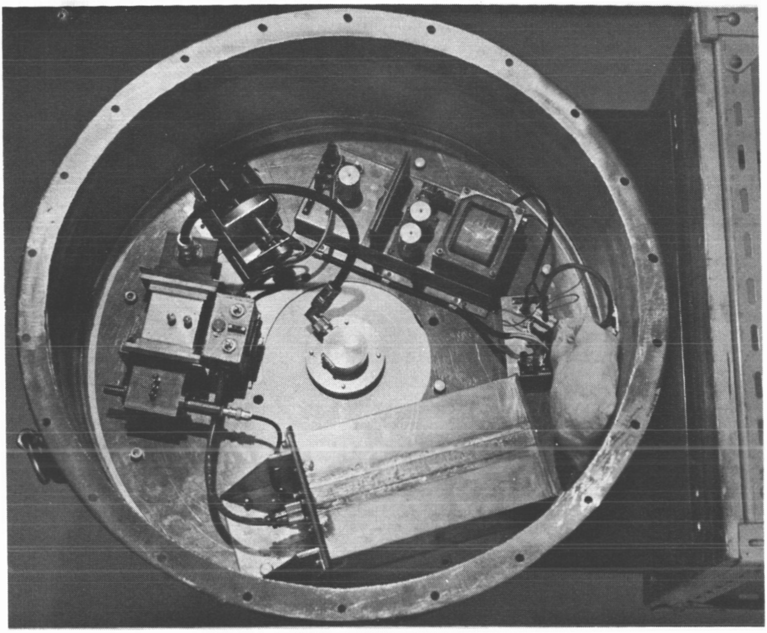


Fig. 33 — Interior view of the beacon.

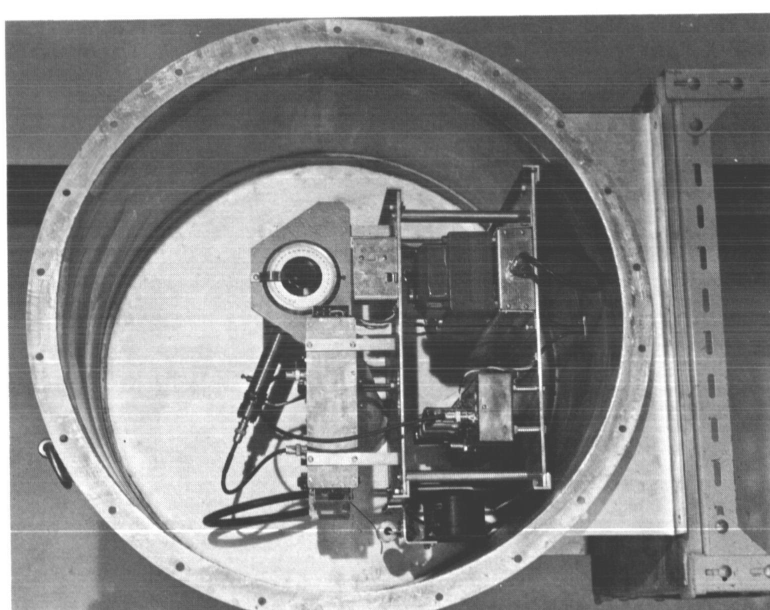


Fig. 34 — Interior view of the transponder.

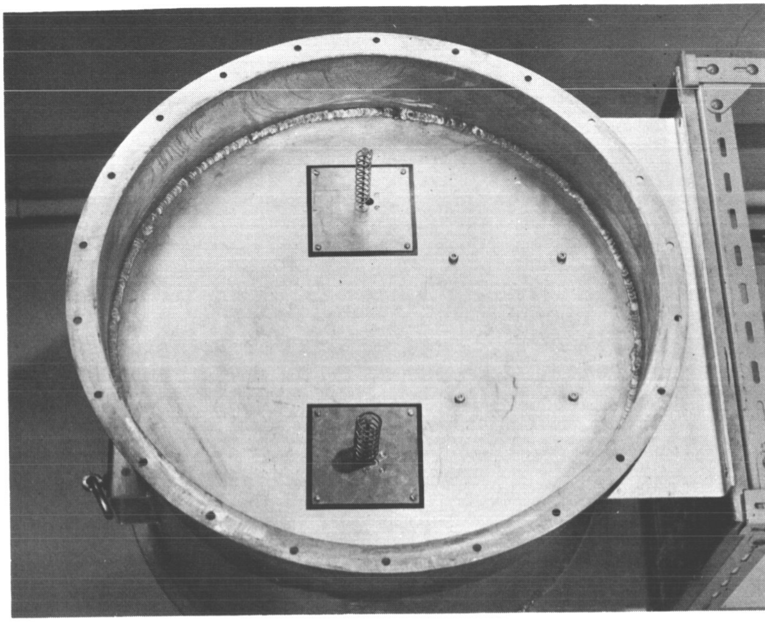


Fig. 35 — View of the Telstar simulator transponder antennas.

The 50-Cycle Alternating Current: 220/380 volts

The 50-cycle power from the national network of L'Electricite de France is carried by 2 medium voltage supply lines. One of these is for regular use and the other is on standby for emergency use; both are connected to the main power switchboard. Since a distance of more than 500 m separates the main building from the power supply building, it was necessary to install at these two points 2 transformers of 630 and 1260 KVA, both of which supply power at 220/380 v. They are complemented by 2 induction regulators which produce a regulated voltage at ±2% for electronic equipment of French origin.

60-Cycle Alternating Current

60-Cycle Blowers, 272/470 volts

The power for the pressurizing equipment of the radome, consisting of five 5 KVA blowers (Fig. 37), is provided by special circuits.

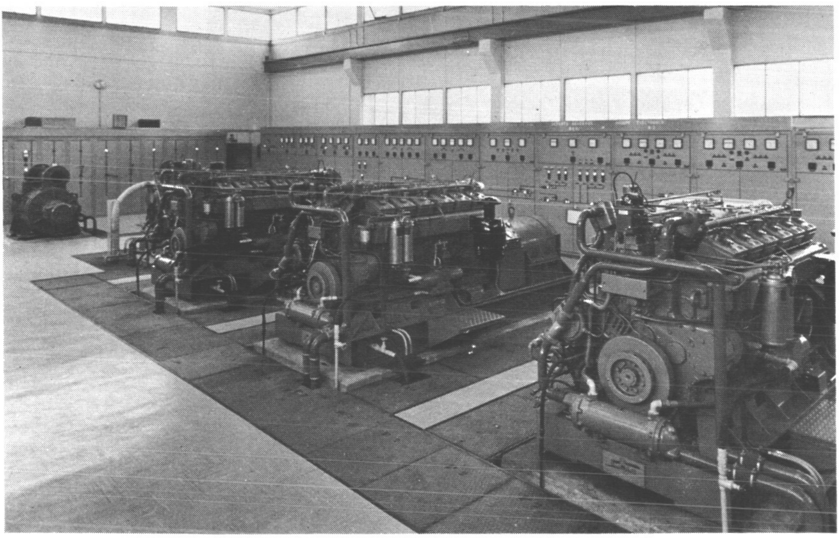


Fig. 37 — Interior view of the power supply building.

In the power supply building, 2 groups of 50/60 cycle converters ordinarily supply the necessary power through 2 lines, one of these being a standby.

In case of power failure from the network, one 75 KVA diesel generator (GE1), in reserve for emergencies, starts up automatically.

Finally a second emergency generator (GE5) of the same power, is held in emergency reserve in the radome auxiliary building. This second group is only capable of operating 4 of the blowers. This obviates the risk of total loss of pressure from a simple switching failure in the control cabinet of this group.

60-Cycle General, 272/470 volts

In the power supply building, 3 250 KV diesel generators, GE2, GE3, and GE4 provide the regular supply.

Normally, the power is supplied by GE2 or GE3 which have manual starters, GE4 being an automatically started stand by.

At critical times, GE2 or GE3 is coupled in parallel with GE4.

The frequency tolerance of $\pm 1\%$ is obtained by a speed regulator of the wattmeter type. The alternators have voltage regulators with an accuracy of $\pm 1\%$.

The power is sent to the radome via 2 separate circuits (for motors and electronic equipment respectively), and to the main building, where two transformers (one exclusively for the computing center) reduce the voltage to 120/208 volts.

60-Cycle Special

Some components of the antenna require a regular power supply of 230 volts at 60 cycles, single phase, with subharmonics less than 0.5/1000.

2 converter groups of 60/60 cycles—8 KVA—1800 rpm with automatic starters, provide this power.

One of the groups is powered by the 60-cycles coming from the 50/60 conversion, the other by the 60-cycle general supply.

At critical times, the two groups are in operation, one carrying the load, the other unloaded on automatic standby; the load transfer can be effected within 0.25 seconds.

These groups fulfill exactly the necessary requirements: no harmonic is above 3%. No matter what the load (from 4/4 to zero) with a power factor varying from 1 to 0.7, the value of the subharmonics remains below 0.5/1000. With the same variations of load and power factor, the voltage is regulated at $\pm 1\%$.

The Power Supply for the Antenna

Power is supplied to the rotating structure through 28 commutator rings on the pivot.

The neutral of the 3-phase a-c supply is omitted; this has no effect on the motors, but creates a need for transformers in the lower cabin for the single-phase circuits.

The commutator rings are protected at the radome annex switchboard by electronically triggered circuit-breakers (Nominal load 90 A) and by special fuses for short-circuits. At the antenna input, circuit-breakers with overload relays break the circuit when the load exceeds 100 A. These circuit-breakers release in case of general power failure, to avoid arcing when the power is re-established.

All the circuit-breakers have the usual thermal overload cutoff which is kept as an emergency provision.

420-400 Cycle Power Supply

In the antenna, two 0.3 KVA groups supply single-phase current at 120 v—420 cycles ±0.25% to the antenna servo loops.

In a small building near the central building, 2 groups produce for the trackers 120/208 volt current at 400 cycles ±2%.

DC Sources

The special sources are:

24 volt current ±5%—filtering 1/1000.

2 batteries in the main building supply the station clock (80 amps) and the telephone switchboard (15 amps).

130 volt current ±4%—filtering 1/1000.

For electronic equipment,

1 battery in the main building.

2 rectifier assemblies in the antenna lower cabin.

220 v—60 amps power for emergency lighting of the radome.

Various sources insure, at 24 volts, the starting of the motor-generators, and at 48 volts, the power for the distribution switchboards (switching and indicators).

Power Supply for the Telephone Transmission Equipment

The telephone terminal equipment of the main building is supplied by a special system (battery-emergency generator—switchboard) standardized for long distance lines (LGD).

Ile Losquet

An autonomous power supply station, composed of a permanent source of single-phase 220 v 50-cycle current from 3 motor-generators which are rotated daily, is installed besides the 200 m tower. Batteries supply the remote monitoring equipment. These batteries can also act as a spare power supply to the beacon lights for the safety of aircraft.

Distribution Switchboards

These have been constructed in a unique design, being made of identical and matching modules, equipped with switches, and mounted on plug-in frames (Fig. 38).

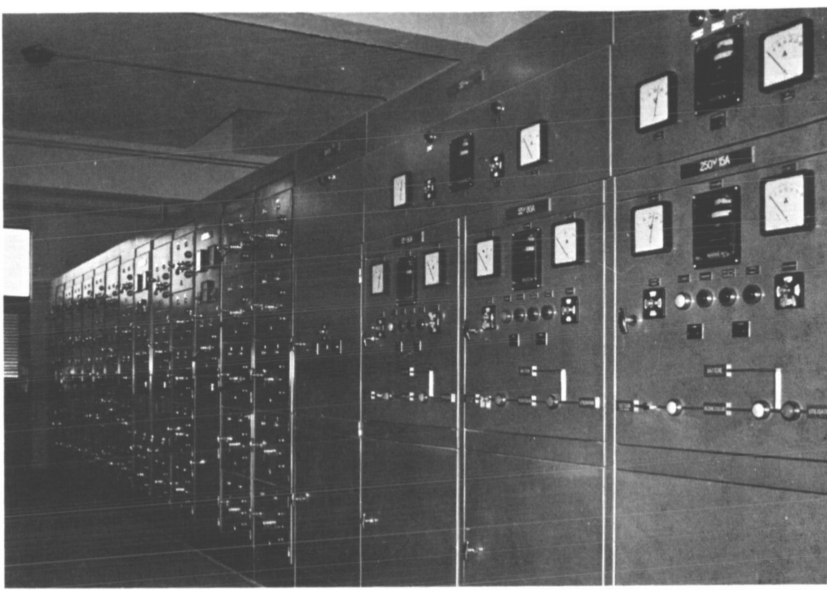


Fig. 38 — Radome auxiliary building—View of the power switch gear.

Beside the switch, each frame carries the usual safety devices: indicating fuses and thermal relays.

CONCLUSION

The Pleumeur-Bodou station has been in operation without failure for all the orbit revolutions which it supported.

Its use has contributed, as well as test data, invaluable experience concerning the functional characteristics of a system both novel and complex.

CNET thus have available sound information for the planning of an operational ground station.