# The APOLLO receiver

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**Summary** The demand for the rapid and reliable transfer of documentary information has grown considerably in recent years and the APOLLO experiment was set up as a forerunner to a full commercial system to meet the demands from libraries, finance houses, business institutions, engineering companies etc.

This article describes the overall system used and gives a detailed description of the Marconi receiver and the basic elements within the system.

## Introduction

Information and Information Technology (IT) are seen as major elements in the technological revolution that is in progress at present. The bringing together of large amounts of information in computer data bases has led to the need for some means of interconnecting and interrogating each data base and then transferring information to those organizations requiring it.

The Commission of the European Communities (CEC) initiated the development of EURONET, a system which allowed direct on-line access to a wide range of bibliographical and other data bases throughout the Communities. This access not only allowed one to search for particular information but also to order copies of the document.

In practice, the problem associated with such a service is not the on-line access but the time taken to deliver a hard copy of the document. Due to the distances involved, which may be hundreds of miles, it may take several days if postal services are used. The alternative method, of course, is to use digital facsimile which will handle text, pictures and graphics in the same document. The difficulties associated with this have been studied in the ARTEMIS report, initiated by the CEC and published in 1981. This showed the magnitude of the requirement across Europe which, at that time, was 10 million document delivery requests per annum, and also considered that an electronic delivery system was feasible. The main outcome of all these investigations was a recommendation that an experiment be carried out to test both the technical requirements and the commercial viability of a delivery system.

From these beginnings, the Article Procurement with On-Line Local Ordering (APOLLO) experiment was proposed and EUTELSAT was approached with a view to making the APOLLO experiment the forerunner of a fully operational commercial system working via the European Communication Satellite (ECS).

## The APOLLO system

### Mode of transmission

The operation of APOLLO could be via terrestrial or satellite networks. At present, with ISDN not fully operational across Europe, it is obvious that satellite communications can provide the right mode of transmission for the needs of APOLLO. To give some idea of the data rates needed, a five-page article from a magazine would be equivalent to between 200 kbit and 1 Mbit of binary information depending on the scanning and transmission techniques used. Digital facsimile equipment is able to print two to three pages of text per second and the transmission system should match that capability, i.e, a 2 Mbit/s data rate.

The main characteristics of the delivery system are:

a) high data rates – up to 2Mbit/s capacity,
b) error-free transmission,
c) point-to-multi-point capability,
d) European coverage,
e) flexible capacity,
f) easy access to the network,
g) low cost of transmission,
h) low cost of capital investment.

The cost element of the system is as important as the technical characteristics in that it is essential that the service is utilized to its fullest extent.

### Overall network

The diagram of figure 1 shows the basic building blocks essential with the APOLLO system. The transmission system operates in a store-and-forward mode. This means that data messages have to be temporarily stored in a source data station until satellite capacity is available. Data received from the satellite is held in sink data stations. Control of the flow of information is accomplished by Satellite Access Controllers (SAC) for the transmit system and by Receive Access Controllers (RAC). The terrestrial network is used to connect the data stations to pass on information requests, orders, commands, etc.

### Receive-only terminals

The APOLLO system uses the satellite for transmission from source to user. It does not allow the user to search for, or order, specific documents. This means that the user requires only a simple earth station, with receive-only capability, situated locally. The block diagram in figure 2 shows the basic elements of a receive-only terminal comprising two major sections, an indoor and an outdoor unit.

### Outdoor unit

The outdoor unit is required to operate over the frequency band 12.5GHz to 12.75GHz. The gain/temperature (G/T) specification is defined for a variety of conditions

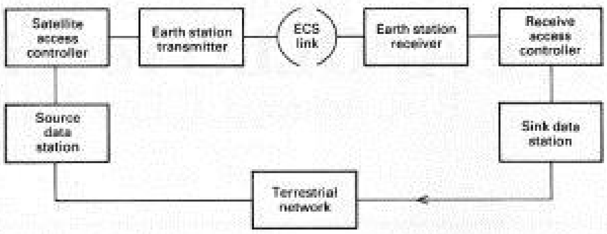


*Fig. 1. APOLLO – block diagram*

and the conjunction of antenna and low-noise converter (l.n.c.) must meet this G/T.

## Antenna system

There are two sizes of antenna, 1.8m and 2.2m. diameter, and in this size range a simple fixed mount can be used as tracking is not necessary. It is, of course, necessary to be able to adjust the antenna pointing position to take account of the different physical locations in Europe and the possibility of using different satellites. This means that the azimuth adjustment must be ≥150° and the elevation between 10° and 50°. These adjustments must be simple to carry out and with a precision that will allow the pointing to be sufficiently accurate for the effective antenna gain to be within 0.4dB of the possible maximum. There are, of course, other operational effects, (such as wind, antenna structure stability, etc) that can reduce the operational gain still further.

The off-axis gain is also defined relative to the gain peak boresight. It is defined as:

$$G = 17 + 25 \log \Phi$$

where Φ is the off-axis angle between 1° and 20°. Beyond 20° the discrimination will be 46dB for 1.8m and 47.8dB for 2.2m.

The antenna is linearly polarized with a polarization purity greater than 30 dB. It is also necessary to be able to adjust the plane of polarization to within ± 0.5° of the polarization plane of the received signal.

To facilitate adjustment, a 360° scale is engraved at the rear of the antenna feed adaptor plate. By using signal-level circuitry in the receiver, and adjustment of the feed adaptor plate, the polarization can be optimized.

## L.N.C

The l.n.c. operates over a range of 12.5GHz to 12.75GHz and must have a sufficient low-noise temperature and through gain to give an overall system gain/noise temperature (G/T) to meet the APOLLO requirement. The noise factor in any system is made up of three major elements:

a) l.n.c input noise temperature,
b) sky noise temperature with antenna on boresight,
c) noise received on side lobes.

There are other minor elements due to the indoor unit noise figure and cross-site cable loss but these are minimized if the l.n.c gain is sufficient. In this case, the gain is 50 dB which reduces the minor effects by a factor of $10^5$.

## Gain/temperature

Table 1 shows the expected G/T for a variety of l.n.cs and the two specified antenna sizes.

The local oscillator used in the system has a frequency of 11.3GHz with a frequency stability of 10 p.p.m.

The mechanical configuration of the l.n.c system comprises two units. A main unit houses the low-noise amplifier (l.n.a) and the i.f amplifier, and a second unit houses the local oscillator. The l.n.a unit mounts directly onto the waveguide flange of the antenna feed output to reduce the losses and so improve noise performance. Both units are waterproofed, as are the connecting cables which run from the l.n.c to the indoor unit.

## Indoor unit

The indoor unit block diagram is shown in figure 3 and its performance requirements are detailed in Table 2. The signals applied to the indoor unit come via the ECS satellite multiservices transponder. The r.f signal is converted down to a carrier frequency in the range 1.2 GHz to 1.45GHz, with a bandwidth limited to 250MHz. The formal specification requires that the indoor unit should be able to handle a signal level of −41dB to −54dBm and can be situated up to 100m from the antenna.

The detailed design of the unit is specified by ESA. The unit has to be frequency agile to allow it to be compatible with the 22.5kHz frequency spacing allocated for APOLLO carriers by EUTELSAT. This is achieved by the use of a frequency synthesizer, adjustable in 200kHz steps over the full 250MHz band. The other element of uncertainty in the indoor unit input frequency is the carrier frequency var-

**Table 1: L.N.C noise temperature**

| 1.8m dia antenna | | 2.2m dia. antenna | |
|---|---|---|---|
| Noise temp (K) | G/T (K) | Noise temp (K) | G/T (K) |
| 297 | 20.6 | 292 | 22.4 |
| 337 | 20.0 | 333 | 21.9 |
| 370 | 19.6 | 369 | 21.4 |

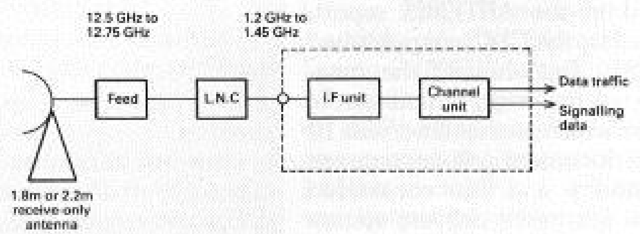


*Fig. 2. Receive-only terminal – block diagram*

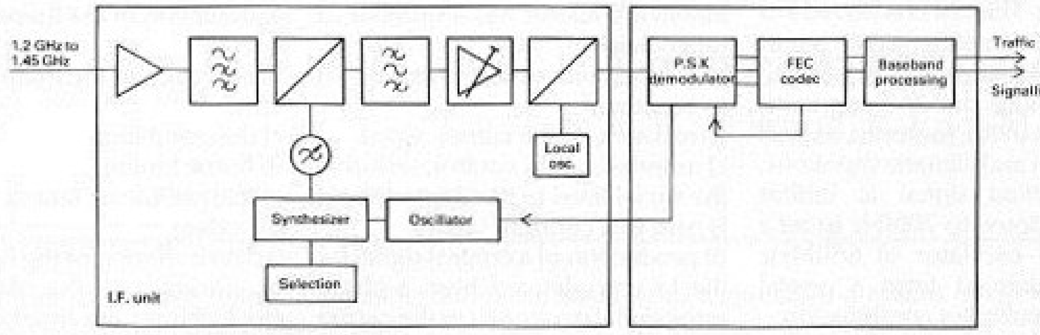


*Fig. 3. Indoor unit – block diagram*

**Table 2: Indoor unit parameters**

| | |
|---|---|
| Input frequency | 1.2GHz – 1.45GHz |
| Input level | –55dBm to –75dBm |
| Noise figure | 15dB |
| Maximum input v.s.w.r | 2:1 |
| Gain variation | 20dB |
| Output frequency | 70MHz |
| Output level | –20dBm |
| Output impedance | 50Ω |
| Maximum output v.s.w.r | 1.2:1 |
| Gain frequency response | 0.4dB over ±1MHz |

iation, which can be up to ±300kHz. This problem is overcome by designing-in a frequency search facility which sweeps the local oscillator over a ±360kHz range.

The input signal arriving at the receiver from the satellite will be part of a composite signal containing other carriers, which cannot be pre-specified. Filtering is therefore required to give protection against interference from these carriers, which may have a mean power spectral density 6dB greater than the APOLLO carrier.

The data is modulated on to the carrier using a four-phase p.s.k modulation method. The user bit rate is intended to be 24 x 64kbit/s, giving a minimum requirement of 1536 bits. This is, of course, increased by satellite multi-service (SMS) framing, and with forward error correction (FEC) encoding applied to the transmitter signal, the channel bit rate will be 3276. 8 kbit/s, i.e, twice the data rate.

The APOLLO system operates in a burst mode in order to be compatible with the existing SMS system. It is not, however, true continuous mode, as SMS is, but a quasi-continuous mode, operating with long transmission bursts of up to 10Mbit/s with additional bits for a synchronization preamble which is 65536 channel symbols long, corresponding to two SMS multiframes. The preamble allows the receiver to synchronize and lock on to the SMS multiframe structure. This is achieved on the baseband processing board in the indoor unit. There are also bits at the end of the burst.

The FEC decoder has to synchronize with the demodulator output signal, with 512 bits of the demodulator synchronizing with the input data burst. The decoder itself has the same specification as the SMS system in that it uses Rate 1/2 convolutional coding.

The data is scrambled before transmission. The APOLLO receiver must, therefore, descramble a data signal that consists of scrambled data and framing mixed with non-scrambled framing. The non-scrambled information in contained in Byte 0 and Byte 32 and is the frame alignment signal (FAS). The remaining data is scrambled to produce sequences that are 32767 bits long before repetition. The only problem that may occur here is spurious acquisition caused by FAS simulation in the synchronized sequence. This function is carried out on the baseband processing board.

## APOLLO receive unit

The indoor receiver is designed as a self-contained unit which can be free-standing or mounted as a 5.25in high shelf (figure 4) in a 19in cabinet. An internal switched-mode power supply accepts 240V or 110V mains and provides +24V, +12V, +5V and –12V d.c rails. The r.f is selected by thumbwheel switches on the front panel. A meter indicates carrier level and l.e.ds show the status of the shelf, including the power supply. Each shelf processes one APOLLO carrier. Should other carriers be allocated to a user site, the output from the outdoor unit has to be split such that the signal can be applied to a number of receiver shelves set to the appropriate frequency. It can be seen that the system is flexible and cost-effective, able to be expanded as user requirements increase.

The shelf is essentially in two parts, an i.f unit and a channel processing system.

### I.F unit

The block diagram of the i.f unit is shown in figure 3. The signal from the outdoor unit, in the frequency band of 1.2GHz to 1.45GHz, is connected to the input of the receiver via up to 100m of cable and a Type N connector. This signal is amplified and filtered before being translated down to 610MHz using a synthesized local oscillator operating in the range of 1.81GHz to 2.06GHz. This first i.f is filtered in a variable gain amplifier which is preset in gain to take account of input level variations due to geographical position in the footprint, as well as l.n.c gain and climatic variations. The amplified signal is further translated down to 70MHz using a fixed local oscillator of 680MHz which is derived from a crystal oscillator/multiplier combination.

The i.f frequency should always be within ±300kHz of its nominal centre frequency. Errors due to satellite ageing effects, l.n.c/local oscillator changes and local oscillator changes in the i.f unit are removed by applying a control signal, derived from the channel unit, to the 6.4MHz voltage controlled crystal oscillator (VCXO) that acts as a reference for the synthesizer. The synthesizing steps are chosen at the front panel, which allows adjustment in 200kHz steps over the full 250MHz input carrier band.

### Channel unit

The channel unit is made up of three basic circuits:
a) p.s.k demodulator,
b) FEC decoder,
c) baseband processing.

These are connected as shown in figure 3.

### P.S.K demodulator

The p.s.k demodulator design is based on the circuitry used in the Marconi P3800 Modem, with suitable modifications that improve the acquisition characteristics and lower the unit cost. The demodulator/modulator has a number of functions:
a) conversions of the signal down to baseband,
b) recovery of the carrier signal,
c) automatic gain control, ensuring the signal level to the demodulator is held to a constant value,
d) production of a control signal for the i.f unit, derived from a phase error signal generated in the carrier recovery circuitry. This signal controls the 6.4MHz VCXO,
e) production of a frequency sweep for carrier acquisition,
f) clock recovery,
g) fault monitoring of clock and acquisition failure and input level.

The acquisition process takes place well within specification, being 30s for initial acquisition and 19ms from burst to burst.

### F.E.C decoder

This function is housed on one card. The circuitry operates up to 2048kbit/s, easily covering the required rate of 1638kbit/s. The card takes in the two baseband signals from the p.s.k demodulator and converts them back to digital signals using the recovered clock. They are used to extract the maximum-likelihood data stream, differentially encode it and check it for phase ambiguity.

### Baseband processing

This circuit interfaces with the outputs from the FEC decoder and processes that data. The functions carried out by the baseband processor are:
a) detection of the frame word pattern,
b) detection of the multi-frame pattern,
c) descrambling,
d) frame timing,
e) derivation of timing signals for decoding,
f) data buffering of the burst signal,
g) tracking of the demodulator clock during the interburst period using a phase-locked loop,
h) line drivers,
i) monitoring.

## Uses of the APOLLO system

The original idea behind the APOLLO experiment was to allow a rapid transportation of documents from libraries and archives. However this is not the only service that APOLLO can provide, it is ideal for any application requiring transfer of information. APOLLO can be used to link separate sites within a large company to transfer design information and it can be used by finance houses and institutions to transfer stock market data to regional offices. When the European Trademark Centre is set up the APOLLO system will allow it to be used by companies, solicitors, etc, for the transfer of documents.

The next phase will come when EUTELSAT II is launched and the receiver will be able to use 0.6m diameter antennas, opening up the system to smaller sites and removing problems of local planning restrictions, etc.

**ZUSAMMENFASSUNG**

Der Bedarf nach schneller und zuverlässiger übertragung dokumentarischer Information ist in den letzten Jahren stark gestiegen und das Experiment APOLLO wurde als Vorläufer eines vollständigen kommerziellen Systems aufgestellt, um den Bedarf von Bibliotheken, Finanzhäusern, Maschinenbaufirmen usw. zu decken.

Dieser Aufsatz beschreibt das gesamte System mit Einzelheiten über den Marconi-Empfänger und über die Grundelemente des Systems.

**RESUMEN**

En años recientes ha crecido considerablemente la demanda de transmisión fiable de información documental y el experimento APOLLO se realizó como una experiencia previa para un sistema comercial completo que satisfaga las demandas de las bibliotecas, compañías financieras, instituciones empresariales, compañías de ingeniería etc.

Este artículo describe el sistema completo utilizado y da una descripción detallada del receptor Marconi y los elementos básicos del sistema.

**RÉSUMÉ**

La demande pour un transfert rapide et fiable d'informations documentaires s'est accrue considérablement dans les récentes années, et l'expérience APOLLO a été mise sur pied comme un avant-coureur à un système commercial complet pour répondre aux demandes venant de bibliothèques, d'entreprises financières, d'institutions d'affaires, de sociétés d'ingénierie, etc.

Cet article décrit le système global utilisé et donne une description détaillée du récepteur Marconi et des éléments de base qui se trouvent au sein du système.