FOURTH EUROPEAN ROTORCRAFT AND POWERED LIFT AIRCRAFT FORUM

PAPER NO. 30

THE APPLICATION OF MULTIPLEX DATA TRANSMISSION STANDARDS TO MEDIUM SIZED MILITARY HELICOPTERS

J. M. BROADLEY

Westland Helicopters Limited
Yeovil England

September 13-15, 1978

STRESA ITALY

ASSOCIAZIONE ITALIANA DI AERONAUTICA ED ASTRONAUTICA ASSOCIAZIONE INDUSTRIE AEROSPAZIALI

THE APPLICATION OF MULTIPLEX DATA TRANSMISSION STANDARDS TO MEDIUM SIZED MILITARY HELICOPTERS

J.M. Broadley, Westland Helicopters Ltd

1. INTRODUCTION

The increasing use of digital processors and sophisticated systems to enhance the operational performance of modern military helicopters has been accompanied by a substantial increase in both intra and inter system signal traffic. The manufacture and installation of the conventional cabling necessary to transfer this data are significant cost factors which in addition, impose severe limitations on system expandibility and the ease with which system modifications can be accomplished.

The requirement therefore exists to provide the units and systems on future helicopters with an on-board communication system which both removes the penalties imposed by conventional cabling while reducing its associated costs.

This has resulted in the development of a number of data transmission standards the majority of which operate on a multiplex principle. Although no universal standard has yet been devised, some exist which are particularly suited to large sections of helicopter signal flow. The two principal standards are MIL STD 1553A and ARINC 429.

Work carried out at Westland Helicopters Limited has shown the applicability of both standards to systems with different functional requirements and signal flow patterns.

This paper examines the impact of multiplex data transmission on such factors as expandibility, flexibility, etc, of the avionic system in general. This is followed by a critical examination of the application of MIL STD 1553A and ARINC 429 to a typical communication system.

2. GENERAL BUSING CONSIDERATIONS

2.1 Flexibility/Expandibility

Flexibility in the present context is defined as the ability of an avionic system to cope with modifications with a minimum of disruption to the remainder of the system.

Considerable cost savings are to be made throughout the life of the aircraft by reducing the amount of cabling between avionic sub systems. This is primarily because of the relatively high costs associated with adding, removing or replacing sub systems ie. loom building, testing and redrawing of wiring diagrams for every modification.

A multiplex data transmission scheme, effectively transfers much of the hardware complexity associated with conventional data transmission into software complexity.

Consider, for example, the steps necessary to implement a modification to a MIL STD 1553A multiplex scheme. The hardware modifications would simply involve breaking the data bus at the appropriate point and installing a coupler box, into which the new sub-system could be plugged. This addition could be carried out in a short period of time without significantly affecting the operation of the other sub-systems.

In order to make the new sub-system operational, it is necessary to modify the software algorithims which effectively tells the sub-system when to transmit and when to receive data. The significant factor to be drawn from this is that the software modifications can be tested and debugged in simulation and when proven, the multiplex system controller can be reprogrammed in a short period of time.

Hence, the inherent flexibility of multiplex systems in general and MIL-STD 1553A in particular allow modifications to be implemented quickly, therefore reducing considerably aircraft 'downtime'.

2.2. Reliability/Integrity

In a cable loom comprising of for example 100 cables there will be at least 200 pins and consequently 200 sockets. This pin count could be considerably higher if the loom passes through bulkheads.

If (in the ideal situation) this cable loom was replaced by a data bus which was a screened twisted pair, the connector hardware could be reduced to 8 pins and sockets.

It should however be noted that this increase in reliability is accompanied by a reduction in system integrity, primarily because multiplex systems inherently create nodes. For example, if several systems share the same data bus, then that bus is effectively a distributed inter system node.

Each sub system would normally have access to the data bus at only one point ie. the remote terminal (RT). This unit might be servicing a number of sub units and providing each with access to the data bus. Hence the remote terminal could be viewed as an intra system node.

The creation of nodes within a system has the effect of reducing the integrity of the system because the failure of a single node can have a catastrophic effect on the remainder of the system. Obviously, if the aircraft bus was severely damaged, no inter system communication could take place.

It is therefore necessary to ensure that (at least) flight critical systems are not starved of data or accept invalid data. The former situation can be guarded against by employing various levels of redundancy.ie. for flight critical systems triple redundancy might be judged adequate, whereas for mission critical systems dual redundancy would suffice.

Redundancy in the data transmission system would normally be restricted to the data bus coupler units and remote terminal/bus interface circuitry.

Invalid data can be detected automatically by the interface hardware checking such factors as parity and coding errors, and errors created within a system can be detected by employing the appropriate built-in-test facilities. However, with conventional systems, having detected the errors, the reversionary mode capability is somewhat limited, whereas in the multiplex schemes with the more widespread use of software, the possibility exists for utilising extensive reversionary mode capability.

Hence when a malfunction occurs, it is possible, under software control to transfer authority from offending units to the appropriate redundant units.

This ability of multiplex systems to cope with a wide variety of both transient and permanent error conditions has the effect of rectifying the integrity reduction imposed by the creation of system nodes. The reversionary mode policy employed would be to a large extent dictated by the results of failure modes and effects analyses carried out on the integrated sub systems and on the integrated multiplex system as a whole.

2.3. Increased Effectiveness

It is generally recognised that the greater the information flow requirement, the greater are the savings to be made by employing a mulit-plex system.

Hence, for an aircraft such as a Westland/Aerospatiale Gazelle, which has a relatively low data tranmsission requirement little benefit is to be gained by using a multiplex scheme whereas for the Lynx and Sea King Helicopters on which the data flow is considerably higher and the cabling more complex, many benefits are to be gained by implementing such a system.

The operational requirements of each aircraft dictates its sensor fit, crew complement and therefore data transmission requirements. Also it is possible by using a multiplex data transmission scheme, to enhance the operational capability of such aircraft.

The increased effectiveness of the individual aircraft and the force in general is due to a number of factors:-

Weight Reduction: It is to be expected that a considerable weight reduction will take place due to the implementation of a multiplex data transmission scheme primarily because of the large saving in cable usage.

A secondary weight saving will take place due to the reduction in interface hardware because fewer interfaces are necessary and also because MIL STD 1553 hardware will shortly be produced in LSI form.

Weight saving allows a higher mission payload and/or greater fuel capacity permitting longer mission duration.

Crew Reduction: Advances in technology have allowed the widespread implementation of large scale integration of electronic components to the extent that it is now feasible to put several computers on relatively small aircraft.

It is necessary to permit these processors to communicate with each other and with the aircraft sensors and displays in a truely integrated avionic system. The inter and intra system data flow would therefore be much greater than on an aircraft with conventional avionics making the cable looming a very significant cost factor.

The acceptance of a common multiplex data transmission standard effectively reduces the cabling and since the processors are likely to be digital, the data to be transmitted is already in an amenable form.

Hence the advent of multiplex data transmission has increased the acceptability of on-board computers by reducing the support hardware costs.

To increase the operational effectiveness of a helicopter and take full advantage of present day technology a large number of sensors are fitted which produce a great deal of information.

Prior to the use of airborne computers it was necessary to have a crew complement sufficiently large to cope with and co-ordinate the influx of data. Much of this excess manual processing can now be performed by computers.

Hence, the introduction of airborne computers has allowed a crew reduction. This has been accomplished by an increase in the data transmitted between crew stations.

The reduction in crew complement and widespread use of computers on aircraft has been made feasible to a large extent by the use of a common multiplex data transmission standard.

Ease of Maintenance: As already stated the use of a multiplex data transmission scheme creates system nodes over which a great deal of inter and intra system data is transferred. This is a convenient point for monitoring the performance of a large number of systems, therefore reducing test time. The ability of a system to perform self test is considerably enhanced by the basic multiplex philosophy. Also, aircraft which incorporate multiplex data bus systems have a high degree of modularity. Therefore, the combination of extensive built in test capability and an increased number of line replacement units will have a profound effect on line maintenance, ie. the spares inventory is reduced and the aircraft 'downtime' is cut to a minimum, therefore increasing force effectiveness.

3. TYPICAL SYSTEM (COMMUNICATIONS)

This section applies two multiplex architectures to a communication system which is considered as typical of that fitted to the medium sized military helicopter. The emphasis will be put on the functional requirements of individual units and the information transmitted between them. This approach is taken because it is not envisaged that such data transmission schemes would be retrofitted to existing communication systems, however, the basic functional requirements are likely to be maintained.

3.1. General Description

The block diagram of the system being dealt with in this section is shown in figure 1.

For each communication set there are two basic units to be considered:

(a) Controllers:

These allow the crew to perform the following functions:

- frequency selection
- channel selection
- mode of operation
- volume control
- self test initiation
- code selection (IFF)

(b) Signal Transmission and Reception Units

Modules, which are situated in the rear bay and nose, perform the following functions:

1) Reception of interrogating radar signals, etc.
2) Signal modulation and demodulation
3) Aerial tuning
4) Reception and interpretation of frequency and code select data from controllers
5) Validation of interrogating signals (IFF)

In addition there is a Communication Control System which consists of two station boxes, a radio selection box, and transmit and mute switches.

Station box functions include:

1) Selection of audio sets
2) Intercom amplification and volume control
3) Connection and switching of mic/tel
4) Intercom fail switch

Radio Selector Box:

1) Standby supply selection
2) Aerial selector
3) UHF mode select
4) Squelch level select
5) Guard frequency enable

3.1.1 Existing Signal Data Flow Analysis

The signals considered here are those which could be transmitted over a data bus. Discrete signals which do not have excessive timing tolerances (eg. ± 1·25 ms) and analogue signals which have an information bandwidth less than 400Hz are proposed as suitable for data bus transfers.

An analysis of the communication system shows that:

1) No signals are transmitted to the interseat console from the other areas.

2) Selector box acts only as a signal source and interconnects five controllers.

3) The I band and IFF systems are isolated from each other and from other sets.

4) The system is highly centralised in the interseat console because data is mainly dispersed from here to the appropriate aerial units.

5) Signal traffic consists of:

Type	No.off	Function
Discrete	118	Frequency select Code select Altitude information Misc rotary and toggle switch positions

Serial Bit Mode	2	IFF code select and HF frequency select
Analogue	2	Estimated to have information bandwidths of 4Hz and 40Hz

3.2 Multiplex Systems

This section considers the application of two different multiplex arrangements to the communication system described in section 3.1.

3.2.1 ARINC 429

From section 3.1 it can be seen :

1) 96% of busable signals are discrete
2) Unidirectional data flow
3) Single source/single sink architecture
4) 94% of discrete signals are at present transmitted in a parallel form.
5) Iteration Rates:

   In the comms system, there is no requirement for data such as frequency and code selection, etc. to be transmitted continuously. Transmission is only required when the data is altered, ie. a new frequency or code is selected.

   There are eight communication controllers located on the inter-seat console occupying approximately 1ft^2 of panel area. The controls consist of:

   a) 17 toggle switches
   b) 4 thumbwheel switches, each with 8 positions
   c) 16 rotary switches with approximately 100 positions
   d) 12 potentiometer controls

The simplest structure which would satisfy the requirements is shown in figure 2. Basically this consists of providing a bus for each source of information, eg. the 14 cables which are required in the conventional system to transfer data from the V.H.F. controller to aerial unit could be replaced by a serial bus. Similarly, for the radio selector box which would be linked via a dedicated bus to the pilot and co-pilots station boxes, the U.H.F. controller and the V.H.F. controller.

Flexibility/Expandibility

Adding a new communication set to the existing system:
In circumstances such as this, it is likely that a serial link would be used to transmit data from controller to T/R, which would not involve any disruption to the existing system. It would be necessary to exercise control over such a system, partly from the communication control system, in which case, buses c, d and e of figure 2 could be extended to the new system which would simply be treated as another sink.

In this scheme, little problem is encountered when new sinks are added, however when a new source is added, a new bus is required.

Replacement of existing sets: It is unlikely in this situation that exactly the same type and amount of information is transferred between new units as there was between those being replaced. If conventional interconnections are used, this will probably require additional cables being added to the existing looms. However, if a data bus system of the type suggested here is used, any signal re-formatting could be software implemented with the result that transmission hardware would be unaffected by such alterations.

There are a number of further modifications which could take place, however these are likely to be only variations on the above themes.

Reliability/Integrity (1)

In the conventional system, where each signal has its own dedicated line the effect of a single cable failure will only affect that particular set and might not even significantly affect the operation of that set.

The multiplex systems shown in figure 2 effectively buses each communication set. Specifically, a bus is proposed linking each controller to its associated aerial unit. Obviously, if a bus fails, that particular set ceases to operate, although the other sets remain unaffected.

The communication control system, however, involves three multisink buses. If any of these buses suffered a malfunction, both the V.H.F. and U.H.F. sets would be affected. Hence, critical nodes are created where the individual sets are integrated.

Depending on the integrity requirement of the systems involved, redundant buses might be required to provide back-up for buses,a, d, and e.

Observations (1)

The system organised with single source/single or multi sink interconnections is attractive for the following reasons:

1) Low technical risk because the existing communication arrangement is maintained to a large extent.
2) Satisfies the non processor communication requirements.
3) Economic handling of low data rate systems such as those involving large amounts of discrete information.
4) Compatible with systems where data flow is unidirectional, ie. communication system.
5) Interface requirements are relatively simple.

3.2.2 MIL STD 1553A

The MIL STD 1553A scheme (figure 3) to be considered here consists of a combined bus control unit/comms. controller/display unit which controls all bus transactions. It is assumed that each aerial unit has remote terminal capability and is directly coupled to the data bus.

Flexibility/Expandability (2)

This scheme is relatively easy to expand because:

1) All units are connected directly to the system bus. Therefore, if a new communication set is to be added to the system, the aerial unit could be simply connected to the bus and the bus controller software altered to accommodate the addition to the signal traffic and also the re-formatted display.

2) No hardware modifications to the basic bus structure are necessary. The only hardware alteration which would be incurred would be to allow the new stub to be connected to the bus. However, redundant bus/stub coupler units could be made available for future expansion which would mean that any new units require only to be plugged into the bus.

Reliability/Integrity (2)

As with other MIL STD 1553A schemes, a high integrity requirement is put on the bus control unit and the data bus because if either of these units malfunctions, the entire system ceases to operate reliably. This problem can be alleviated by providing critical units with a redundant back-up unit. This can easily be achieved when more than one unit in a system has processing capability and can therefore host the critical software which only becomes operational when the primary unit malfunctions.

In the communication scheme, only the system multi-function controller is complex enough to merit processing capability. This software performs functions associated with:

- Data control
- Error control
- Display formatting
- Interpretation of operator commands

All other modules (aerial units) are performing relatively simple functions and have no processing capability. Hence in the communication system there are no units capable of providing back-up to the multi-function controller. However, if this system was to be combined with another such as the navigation system, some of the units belonging to this system might be capable of performing BCU functions.

Observations (2)

The following are some of the significant factors concerning the application of a MIL STD 1553A system.

1) Very low bus loading.

2) Easily expanded to encompass additional crew station requirements.

3) The flexibility of the standard encourages a high degree of integration, i.e. multi-function display controllers.

4) Extensive reversionary mode policies can be implemented.

5) Hardware complexity considerably reduced.

4. CONCLUSIONS

This paper has demonstrated an analysis/synthesis process and identified a number of significant aspects of adopting a multiplex data transmission scheme. An analysis of a conventional communication system is carried out to determine the functional requirement of the individual units, their physical distribution and the signal traffic between them.

This was followed by a brief examination of 2 multiplex schemes which would satisfy the general data flow requirement of the communication scheme.

The ARINC 429 scheme was shown to be very attractive because it allowed much of the conventional system simplicity to remain. The relatively simple functional autonomy which exists between conventional system units could also be maintained with no need to include complex units to control the flow of data on the buses. This can be achieved because ARINC 429 is a unidirectional system.

A high level of system integrity could be achieved because the successful operation of the entire system did not depend on a small number of critical units. Also, this arrangement is flexible enough to allow new sets to be added without a great deal of disruption to the remainder of the system.

The MIL STD 1553A scheme was shown to be capable of coping with the data flow and general system requirements although it is possibly more powerful than is necessary for this particular communication system. It has been established that the expandibility requirements of such systems are considerable and can inflict considerable cost penalties. MIL STD 1553A architectures are more easily expanded than equivalent ARINC 429 architectures and therefore lower 'life cycle costs' are to be expected.

A single MIL STD 1553A scheme imposes a reduced integrity on the system; however, this loss is more than recovered by the ability of such a system to implement reversionary mode control.

The equivalent basic ARINC 429 scheme has a high integrity; however, because it is less integrated than the 1553A scheme, a general reversionary mode policy is impossible to implement and therefore a general increase in ARINC 429 system integrity would be costly.

BIBLIOGRAPHY

1) Aircraft Internal Time Division Command/Response Multiplex Data Bus MIL STD 1553A April 1975.

2) Mark 33 Digital Information Transfer System (DITS) ARINC SPECIFICATION 429 June 1977.

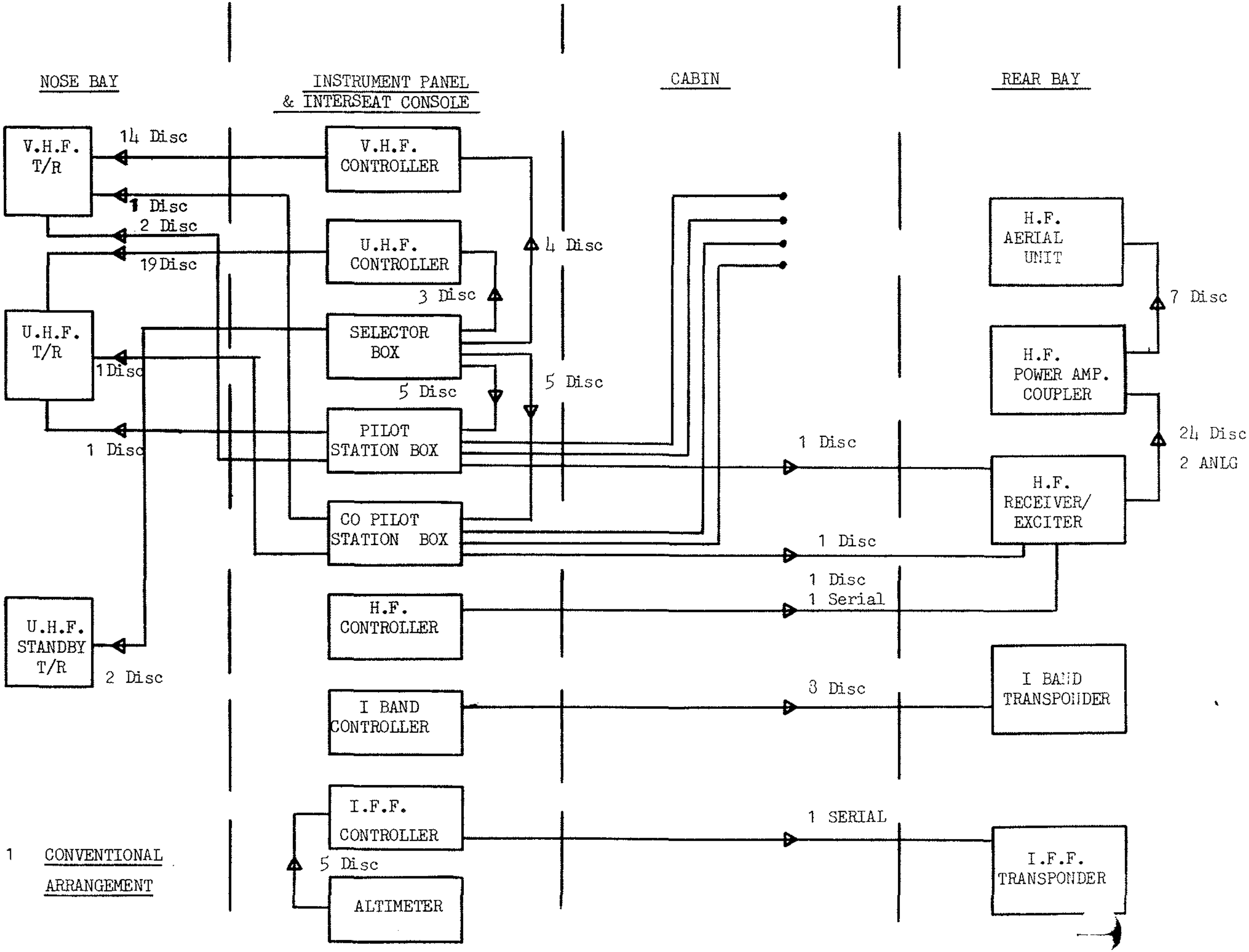

FIG. 1 CONVENTIONAL ARRANGEMENT

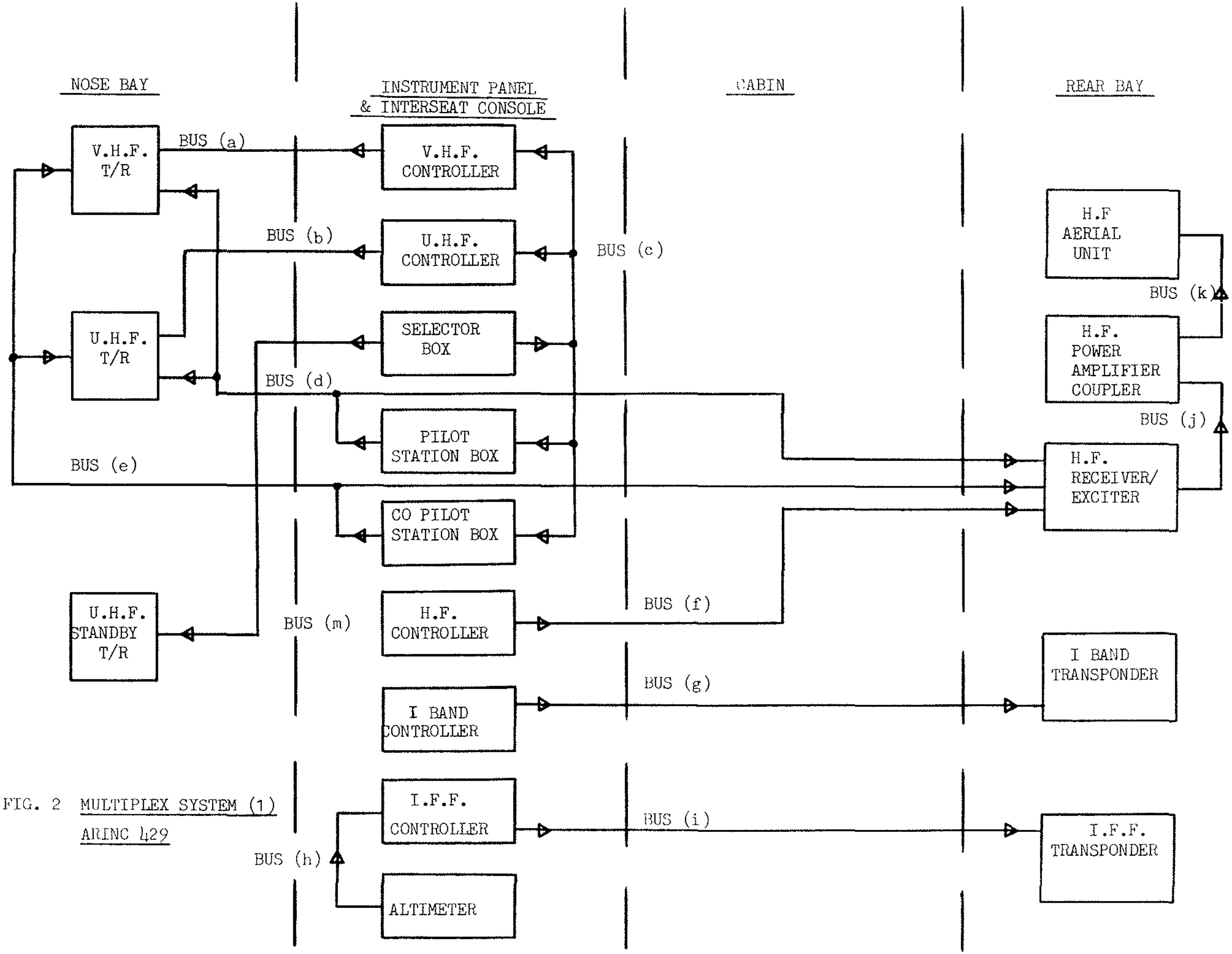

FIG. 2 MULTIPLEX SYSTEM (1)
ARINC 429

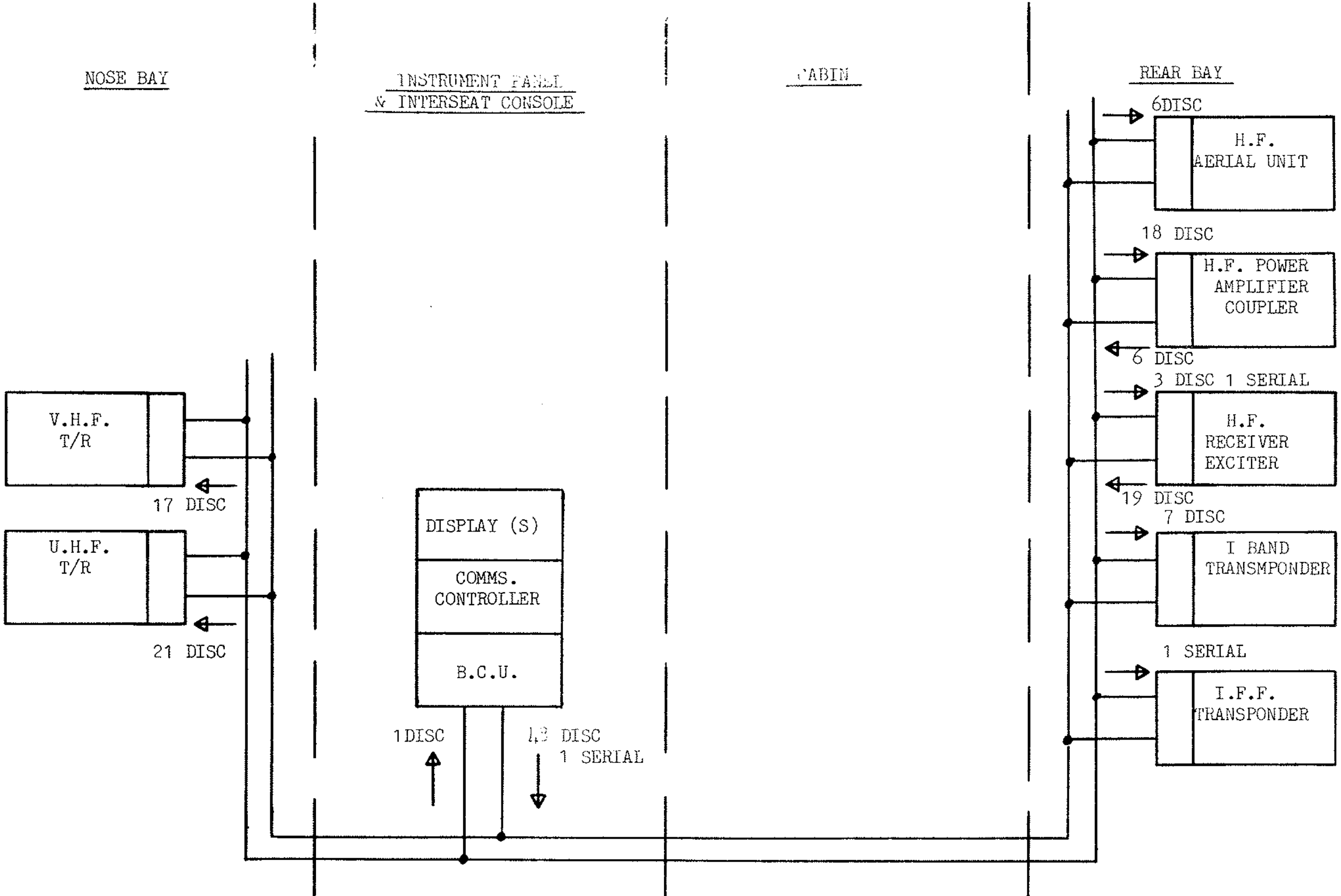

FIG. 3 MULTIPLEX SYSTEM (2)
MIL STD 1553A