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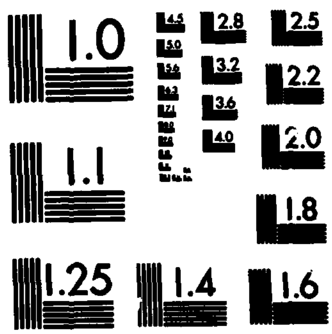

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APPLICATION OF VIDEO MULTIPLEXING TO DESIGN OF COCKPIT DISPLAY SYSTEMS

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Video multiplexing plays an important role in the success of the Advanced Integrated Display Program because it facilitates the use of cathode-ray tube displays in the cockpit with extreme simplicity, high reliability, economy of space and weight, unusual flexibility of operation, and easy adaptability to different arrays of aircraft sensors. This report describes and explains the NADC laboratory demonstration of the wide-band frequency-division video multiplex system.

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INTRODUCTION

The cockpit of a modern combat aircraft must accommodate numerous specialized displays for sensor systems and fire control systems in addition to the normal complement of flight to instruments, engine instruments, aircraft system instruments, and navigation instruments. This multiplicity of instruments and displays confronts the pilot with a mass of information which competes for his attention. At any given time during the flight, the pilot is concerned with only a selected few of the large array of instruments surrounding him. A simple flight scenario is composed of phases such as takeoff, climb, cruise, approach to target, at target, leaving target, cruise, approach to landing, landing. The particular phase of flight will govern which instruments will get his attention.

Regardless of the particular phase of flight a pilot has his own priorities. Overriding all others is the necessity to fly the airplane. This priority exists during all phases of a mission and demands that instruments presenting flight data occupy the prime location in the pilot's field-of-view and that the information they display be presented continuously. His next concern is navigation. This chore he must attend to with sufficient frequency during the flight to get him to the target and back to base. With these necessities attended the pilot may then apply his attention to the demands of the mission and its array of sensor and fire control displays.

STATEMENT OF THE PROBLEM

The problem is to present the required information to the pilot in a manner corresponding to the priorities from the pilot's point-of-view and consistent with the demands of the various phases of flight. The desiderata for cockpit display and instrument improvement are that visual clutter of instruments be reduced, equipment reliability be increased, cost reduced, and maintenance and modification be made easier and faster.

Current cockpits are jammed with wire cables, tubing, pipes, linkages, switches, and all manner of controls. Instrument panels abound with single purpose displays. Space is in extremely short supply. The problem is to design whatever must be located in the cockpit to require minimum space and be easily installed, removed or changed.

WIDEBAND RF MULTIPLEXING AS A SOLUTION

A means of transmitting a diversity of display information over a single transmission line can contribute important advantages to the design of avionics systems having multiple sources and multiple displays. Such a scheme allows the designer to physically separate the display equipment from the image generation and signal processing equipment. The alternatives in equipment size, form, weight, location, and simplification of interconnecting cables made possible by this approach give the equipment designer a flexibility that he previously did not enjoy.

Because dynamic graphical displays require the input of vast quantities of data per second, the TV raster is an ideal format to organize and transmit signals which represent a variety of graphics that vary in real time. The use of a raster format for all display signals makes possible the use of frequency-division multiplexing which permits the exploitation of important practical system benefits.

HOW IT WORKS

The multiplexing of display signals by "frequency division" is achieved by using a separate rf carrier for each image format to be displayed. The raster signal representing a complete image is used to modulate one of the carriers. A separate rf carrier frequency is needed for each "picture" to be displayed.

If, for example, two sets of images are to be multiplexed, a transmitter for each is required. Each transmitter is modulated by one of the image signals which has been generated or converted to raster form. The raster-modulated rf output of each transmitter is mixed in a passive summing junction. Thus, the output of the junction will be a composite of the two signals and can be applied to the input of a single coaxial transmission line. Either of the two display images can be displayed at the other end of the line by tuning a receiver-demodulator to the frequency of the carrier containing the desired image signal. A separate receiver, tunable to the appropriate carrier frequencies, is needed for each display device to be operated in the system.

LABORATORY SYSTEM

The Naval Air Development Center (NADC) laboratory model for demonstrating wide-band video multiplexing provides for the transmission of five sources of raster-type video over a single coaxial transmission line. These signals may be displayed on any one or any combination of four separate display units. The system is arranged to provide a second or alternate coaxial transmission line containing the same multiplexed raster signals. This cable duplication is meant to provide increased system security against cable failure or combat damage.

Figure 1 is a block diagram of the NADC wide-band multiplex system. The five blocks labeled "XMTR" are small low-powered, vestigial sideband, TV transmitters. Each transmitter has a different carrier frequency conforming to the standard VHF-TV channels 2, 4, 5, 7 and 9. Transmitter output level is approximately 500 mv across a 75 ohm output impedance. The five transmitters permit five independent sources of video information to be multiplexed for the system. Input signals to the transmitters must be in the form of a composite synch and video signal.

The output of each transmitter connects to a passive power divider (÷) which splits the signal into two output signals. One output signal is applied to summing junction Σ_A and the other to summing junction Σ_B. Thus, each transmitter feeds separate summing junctions whose outputs are composites of the five input signals and constitute the multiplexed signal for the system. The composite output of each junction feeds a coaxial transmission line or bus. Incorporation of two summing junctions in the design provides the system with a duplicate bus containing identical display information.

In an actual aircraft installation a system of this design permits the signal generation and multiplexing equipment to be located in the aircraft at the designer's convenience. The total information to be displayed in the aircraft cockpit is simultaneously transmitted to the cockpit displays on a single RG59 coaxial cable. In the NADC system a duplicate cable or second bus has been provided to demonstrate system redundancy against equipment or cable failure.

Referring to figure 1, bus 1 coming from the output of summing junction A (Σ_A) runs through the aircraft to the cockpit where it feeds the input of a series of directional couplers. Each directional coupler has two output ports, one of which is used for the parallel connection to the next receiver in the loop and the other connects to the input of a multi-channel VHF TV receiver whose output drives a CRT cockpit display. In this arrangement four receivers and their associated displays are

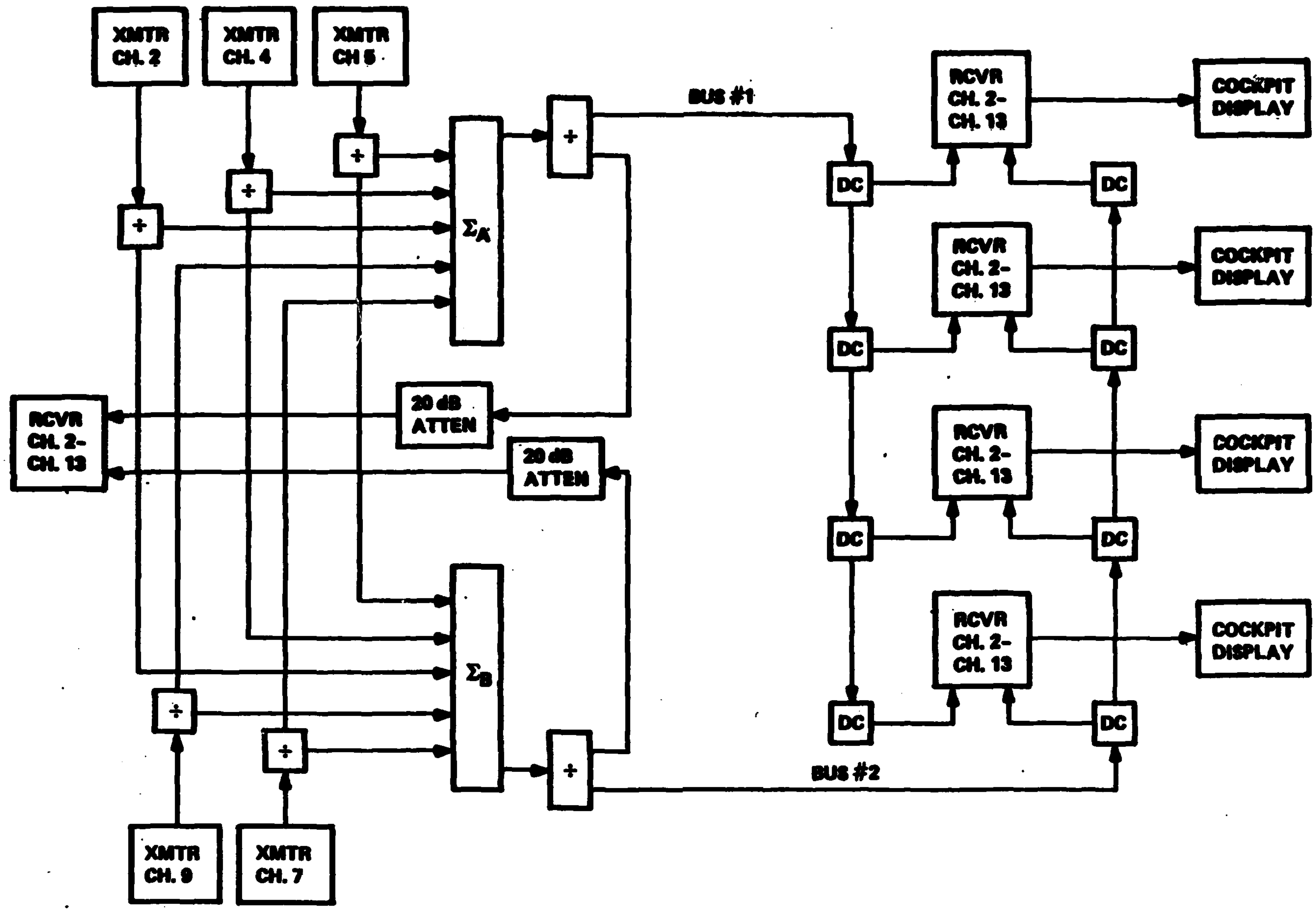

Figure 1. Block Diagram of NADC Wide-Band Multiplex Scheme for Advanced Integrated Display Systems (AIDS)

driven by the bus. Any one of these four cockpit displays can be made to present any one of five available display patterns by tuning its receiver to the VHF channel containing the desired imagery.

Bus 2 and its associated directional coupler chain contains information identical to the information in bus 1. This second information bus gives each cockpit display the ability to receive its information from either of two separate electrical and physical paths in the aircraft.

Figure 1 shows that the NADC laboratory model has a power splitter (÷) inserted at the input of each bus to feed a sample of its multiplexed signals to a VHF TV receiver. The VHF receiver can be used for purposes such as driving a monitor display or a video tape recorder.

In this system each cockpit receiver must select either bus 1 or bus 2 and one of five channels of video information available on each bus. This is done by providing a rotary switch for channel selection and a toggle switch for bus selection on each receiver. In the NADC system, circuitry has been provided in each receiver to enable both bus and channel selection to be accomplished remotely by computer generated digital signals as an alternative to manual switching at the receiver. Remote digital control in an actual aircraft would be accomplished using a MIL-STD-1553 bus.

Performance

The laboratory test model of the wide-band multiplex system successfully demonstrated full multiplex operation of the five images sources and the four display units. Any of the five image forms could be presented on any or all of the four displays. Quality of TV video and line graphics was judged by subjective viewing to be good.

The system has a mean horizontal resolution of 410 lines and an eight step gray scale. Measured mean 3-db bandwidth per channel is 3.05 MHz (mean 6-db bandwidth is 3.48 MHz). Minimum adjacent channel carrier rejection was 53 db below the carrier level. No cross talk was measurable between bus 1 and bus 2.

AIRBORNE SYSTEM

In an actual flying model of a multiplex system the VHF receiver and directional couplers could be incorporated as an integral part of the cockpit display unit. If the directional couplers are mounted externally a display unit would require only two coaxial cable connectors, a twisted pair line for digital switching of receiver channel, and a power connection. In a system using only one bus and manual display selection the cable requirements are reduced to one power cable and one coaxial cable per display unit. The estimated volume occupied by the VHF receiver and associated digital switching and internal test circuitry is 40 cubic inches or about 5" by 8" by 1". (See figure 2.)

VIDEO MULTIPLEXING USING A FIBER OPTICS BUS

At this point mention should be made of an alternative means to implement frequency division multiplexing. In 1977 a multiplexing system using flexible optical fibers as a transmision medium was demonstrated by Sperry-Univac*. In this system the raster-modulated rf carrier is used to modulate a light source whose emission acts as a carrier on a fiber-optic transmission line. Transmitters and receivers can be either arranged on a loop or a point-to-point bus scheme. While point-to-point capability of fiber optics is well known, Sperry-Univac investigated the loop configuration using 3 transmitters and 3 receivers. (See figure 3.)

*Equipment Description and Theory of Operation AIDS Fiber Optics Video Bus System. Sperry-Univac Report PX 12402, October 1977.

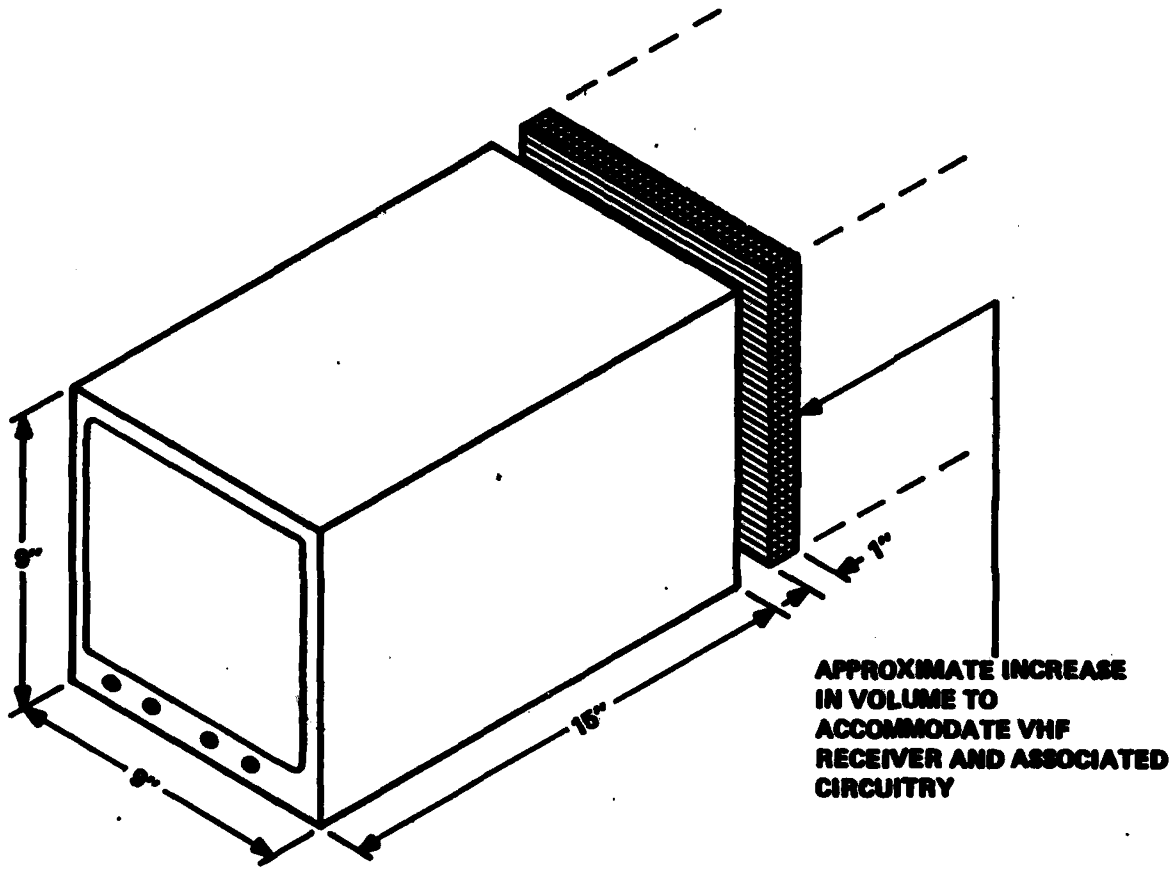

Figure 2. Physical Form of Flying – Model Video Multiplex Display Unit

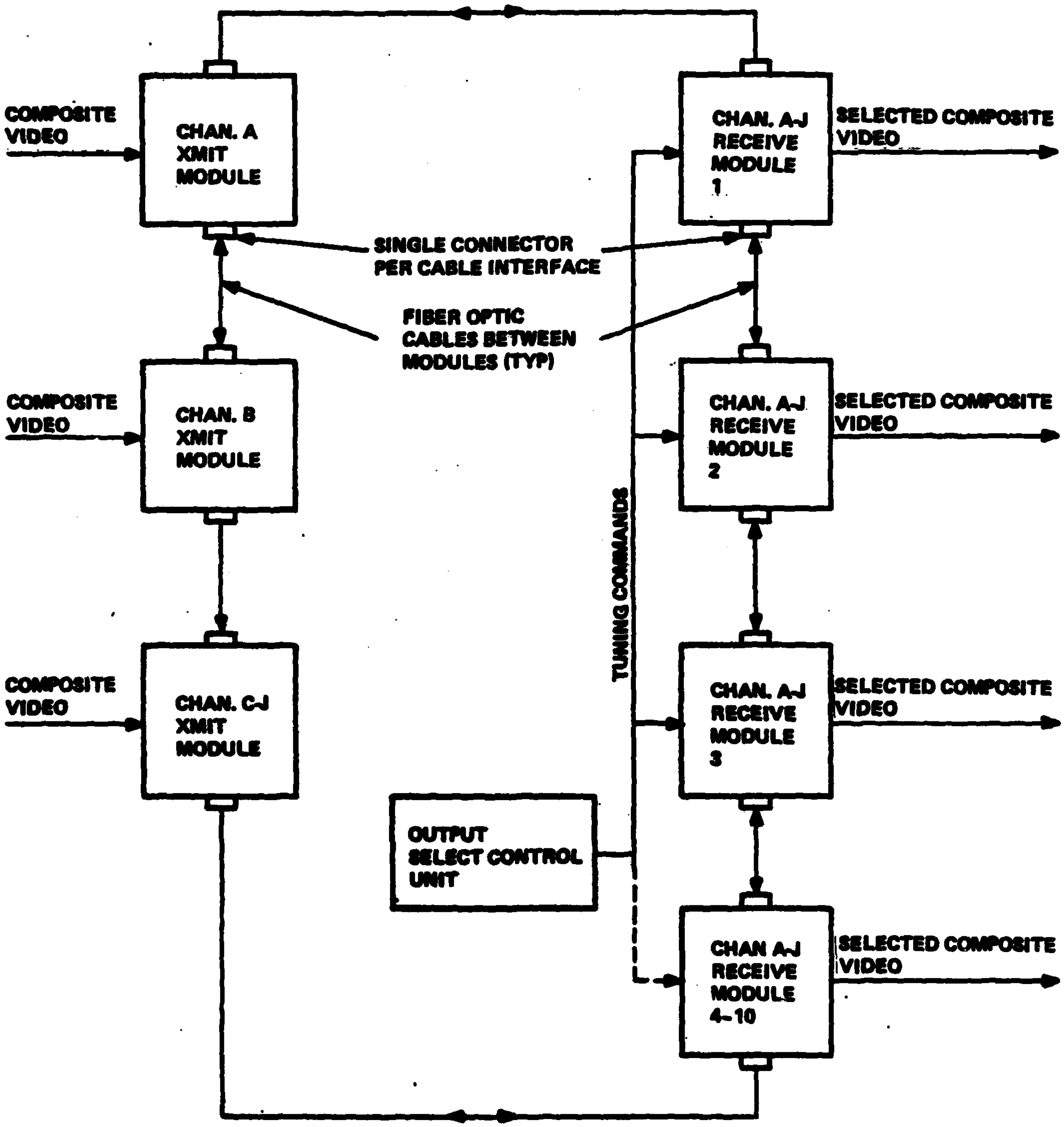

Figure 3. Loop Arrangement of Fiber Optics Video Multiplex System

The Sperry demonstration of the fiber-optics multiplex system was not done with a fully redundant system. Only the receivers were redundant, the transmitters being connected in series. One of the three video channels was a base-band channel (DC to 7 MHz) whose picture quality was inferior to the rf carrier channels (42.8 MHz and 64.2 MHz). Deficient or degraded low-frequency response caused raster tearing (vertical retrace). Re-transmission, which is necessary in the optical loop configuration, served to intensify the effects of base-band low-frequency degradation. The base-band also caused interference with the rf carrier channels.

Re-amplification and re-transmission of the multiplexed spectrum results in a 1 to 2 db loss of linearity after each re-generation. These losses were evidenced by the reduction of quality of fine picture detail which was particularly noticeable on those displays at the end of the transmission line.

This effect would, of course, be compounded with the addition of more displays. Another drawback of this implementation is the need to make phase re-adjustments on each receiver if cable lengths are altered or a receiver or transmitter is added to the loop.

While frequency division multiplexing using fiber optics transmission has been demonstrated as a workable small system, its performance does not yet appear to be equal to the coaxial system which can be expanded to accommodate large numbers of transmitters and receivers. It is apparent that further development effort will be required to advance its performance. Such an effort is now underway at the Naval Avionics Center, Indianapolis where fiber optics technology is being investigated.

ADVANTAGES OF WIDE-BAND MULTIPLEXING OVER PRESENT AVIONICS INSTALLATION

Conventional avionics systems usually come in several component units rather than a single package. The simplest division of equipment consists of a sensor unit and a display unit. In such arrangement the display unit would most likely contain the circuitry for transforming the output signals from the sensor into wave forms and video pulses required to produce the appropriate display image. In other system arrangements the circuitry for converting sensor signals to display signals is incorporated in a "signal processor" unit whose input signals come from the sensor and whose output signals drive the display. Either approach results in a display unit whose mechanical and electrical design must accommodate signals peculiar to that system and therefore require special cables and connectors. This makes the display a specialized, single purpose equipment. Thus, the unit itself and the space it occupies in the cockpit is dedicated to one function only.

The typical aircraft avionics configuration is composed of a number of these specialized electronic systems. Bulky cables and special connectors which are heavy and space consuming characterize the typical installation. Each of these electronic systems including their displays is restricted to its own special purpose. Should a change in the mission of the aircraft require different sensors or avionics, major costly alteration work would be required to remove permanent installations and re-install new special purpose equipment. Any replacement cockpit-display equipment would be physically constrained to the weight, size, and form of the equipment which had been removed.

Simplification of Installation

By adopting the raster format for all display signals and the use of frequency-division multiplexing for transmission and selection of the desired imagery, large reductions in quantity and bulk of system cabling can be obtained while also realizing a simplification of cockpit display installation along with easier maintenance.

Reduction in Wiring

The simplest application of the wide-band multiplex scheme would require a power cable and one coaxial cable to connect a cockpit display unit to the system. More complex systems, like the NADC laboratory system, uses two coaxial information busses and remote digital switching to select either of the two busses or any of the system display formats. A cockpit display unit in this system would require only a power cable, a twisted pair, and two coaxial cables to connect to the system. There would be no problem in accommodating the necessary cables in a single cable connector on the display unit should this be considered desirable.

System Flexibility

In the raster multiplex system the input signals and voltages to all cockpit CRT display units are standardized. The input cables and connectors are identical for each CRT display unit making each display instantly interchangeable. The CRT display becomes a standard box, usable with any avionics system which could be installed in the aircraft subject only to the requirement that the output signals be converted to TV-raster, composite synch and video form.

In addition to the physical standardization of cockpit display units, wide-band multiplexing provides an intrinsic system flexibility. Any cockpit display can be made to present any of the display formats available in the system giving an unprecedented operational flexibility. Any existing aircraft electronics system requiring graphical display can be replaced with a completely new and different avionics system by merely coupling its composite synch and video signal into the input of one of the system multiplexer transmitters. No alteration of cockpit display hardware or cockpit wiring is required. All equipment and wiring changes are confined to the electronics compartment in the fuselage and necessary sensor installation on the airframe. In modifying or repairing avionics using the multiplex system the work is accomplished in the most accessible and easiest part of the aircraft to work on. Expensive and time consuming work in the cockpit is avoided.

Equipment and Wiring Redundancy

The NADC laboratory system provides two separate physical paths for display signals from the aircraft electronics bay to the cockpit. The two-bus system greatly reduces the possibility of complete display system failure from malfunction in cables and connectors or from combat damage. Further redundancy is achieved because any of the CRT cockpit displays can be used to present any display format in the aircraft system. This feature gives the pilot a threefold backup against equipment failure of the CRT display units in the cockpit.

Maintenance

Electronic maintenance is at its most difficult when it involves equipment on the pilot's instrument panel in the confined cockpit of a combat aircraft. The multiplex system, because of its simple wiring and minimal number of connector pins increases the inherent reliability of the system. The physical and electrical standardization of the display units, which can be readily removed from the panel, simplifies the electronic maintenance work in the cockpit. Since all the cockpit CRT displays are interchangeable, maintenance can be reduced to replacement of a malfunctioning unit with one of known performance. Standardization of display units facilitates the ground maintenance by reducing the multiplicity of equipments and therefore the scope of detail to be mastered by the technicians. It simplifies the test racks and test equipment required and minimizes the spare parts inventory.

Cost

Life cycle costs of aircraft avionics using the multiplex system would be significantly reduced because equipment standardization and cabling simplicity increases reliability and maintainability. Equipment standardization yields cost reductions due to savings on higher production runs. Complete interchangeability of all CRT displays in the cockpit make possible significant reductions in spare parts and spare equipment inventory.

CONCLUSIONS

Any aircraft display system where 410 line resolution is adequate can realize outstanding benefits by using wide-band video multiplexing. Most apparent of the advantages is the simplification of the system so that only input power and a couple of coaxial cables are needed to connect the display to the system. The system affords a high degree of flexibility in operation and in ease of modifying the aircraft avionics installation to equip the aircraft with electronics appropriate to different missions.

The inherent simplicity of the wide-band multiplex system increases the display system reliability. Its flexibility results in multiple backup of equipment and cables. In turn these qualities produce ease of maintenance, improved logistics, and lower life cycle costs.

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