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DESIGN OBJECTIVES FOR TELEMETRY R-F TRANSMISSION LINKS FOR THE PERIOD 1960 TO 1970

(SECOND REVISION)

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ABSTRACT

Performance characteristics, design limitations, and special operational features required in a general-purpose UHF telemetry transmission link are presented. Separate consideration is given to the transmitter, preamplifier-converter, distribution amplifier, main receiver, and receiving antenna portions of the link. Flexibility of operation and provision for adapting the ground station complex to several basic applications are emphasized.

Copies of this document are available at $0.75 each from the Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.

FOREWORD

This report recommends design objectives for a basic UHF telemetry transmission link that will satisfy the requirements of most Navy missile programs. Performance characteristics are specified for transmitters, receivers, and receiving antennas for both the 1435- to 1535-Mc band and the 2200- to 2300-Mc band. This is the second revision of the design objectives.

The requirement for vacating the present VHF band was set forth in CNO Instruction OPNAV 02410.15 of March 1958, which calls for phasing out telemetry operations in the 225- to 260-Mc band by 1 January 1970.

This document supersedes NAVWEPS Report 7202 on the same subject (Design Objectives for Telemetry R-F Transmission Links for the Period 1960 to 1970), which was published in October 1961. Work on the project was accomplished under Bureau of Naval Weapons Task Assignment RMWC-52-036/211-1/F009-13-01.

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INTRODUCTION

The design objectives set forth in the sections that follow are recommended for use as guides in the development of telemetry transmitters, receivers, and receiving antennas that will be required in Navy missile programs during the period 1960 to 1970. Performance characteristics are specified for a basic system designed to satisfy the requirements of the large majority of user groups.

The requirement for vacating the present 215- to 260-Mc telemetry band by 1 January 1970 necessitates the development of equipment now, if usable hardware is to become available by 1965. Subsequent development and refinement of early models should allow final design objectives to be satisfied prior to 1970. The specifications will indicate the initial design objectives to be achieved by 1965, and the final design objectives to be achieved by 1970 where difficulties may be encountered because of state-of-the-art limitations. Each set of objectives will be reviewed annually and revised in accordance with the latest developments in components and new requirements specified by user groups. This report represents the second revision of the original design objectives set forth in NAVWEPS Report 7161 (NOLC Report 538) Design Objectives for Telemetry R-F Transmission Links for the Period 1960 to 1970, which was published in January 1961. The majority of the revisions contained herein are in the form of more detailed requirements for the transmitter, preselector, and channel-selection receiver.

The presently assigned, but little used, telemetry bands of 1435 to 1535 Mc and 2200 to 2300 Mc are considered to be the areas in which most of the future telemetry data transmission will take place, although there may be a requirement for some special telemetry links above 5000 Mc.

If the additional propagation losses encountered in shifting from the 225-Mc band to the 1435- or 2200-Mc region are to be offset effectively, it becomes necessary to make improvements in the following areas: (1) an increase of transmitter efficiency to allow more radiated power for a given power input, (2) a reduction in the size and weight of the transmitter and associated power supplies, (3) use of higher-gain directional antennas, and (4) an increase in the sensitivity characteristics of the receiving system.

In considering the possibility of increasing transmitted power, it becomes apparent that the present limitations of size, weight, and available input power to a missile-borne telemetry transmitter will remain essentially the same for present missile programs. Future requirements, however, may be more restrictive, in that space and weight allowances for instrumentation equipment may be reduced considerably below those allowed in current applications. Survey results indicate that a 50-cu-in. transmitter (including power supply) is necessary to satisfy the space requirements for several Navy missile programs. But another group of missiles will require that a 2-watt UHF transmitter fit into a space of less than 6 cu in. (not including power supply). No practical solution is seen for the latter requirement at this time.

Any telemetry equipment for the higher-frequency bands must be designed with space restrictions in mind. Power tubes that will operate in the 1435- or 2200-Mc bands are becoming smaller and more efficient, and the rapid strides being made in the application and improvement of solid-state devices bring the 50-cu-in. transmitter closer to reality each month. There is, however, a continuing need for development of special vacuum tubes or solid-state devices specifically designed to function efficiently and with a high order of stability in the ultra-high-frequency telemetry bands.

The unpredictable behavior of missiles and the wide variation in flight patterns practically eliminate the possibility of using higher-gain directional transmitting antennas. Omnidirectional radiation characteristics are still essential in most Navy test programs.

The receiving antenna offers the greatest possibility for making up the losses encountered in going to a higher frequency. The increased gain obtainable at the receiving antenna, by using narrow beam arrays, is limited primarily by the problems encountered in reliably acquiring and tracking a missile in the many and varied flight patterns encountered at a test range. Shipboard installations may be further handicapped by physical limitations in maximum allowable size and weight. The receiving antenna therefore becomes a compromise between possible gain and the limitations of size, weight, and tracking ability.

The use of new devices, such as parametric, maser, or traveling-wave amplifiers, offers considerable possibility for obtaining high-frequency telemetry receivers with improved sensitivity characteristics, through reduction of front-end noise. If these devices are to be utilized to full advantage, however, it appears necessary to separate the receiver into two main parts. The receiving antenna and the receiver front-end would be designed as a unit to be mounted on the antenna mounting pedestal. The remaining portion of the receiver would be located some distance from the antenna assembly.

The receiver front-end would consist of a low-noise amplifier, connected directly to the antenna feed system, and a converter to reduce the carrier frequency to a few hundred megacycles. The amplifier-converter would preferably be of a broad-band type to minimize the stability and tuning problems at the antenna that might normally be encountered. Inaccessibility of the antenna structure and the severe environment to which it is subjected make it imperative to minimize or, if possible, to eliminate replacement or adjustment of associated equipment, except for periodic maintenance.

The main portion of the receiver would provide the necessary channel selection, amplification, bandwidth determination, and detection functions normal to a telemetry receiver. Multicouplers or distributor amplifiers between the receiver front-end and the main portion of the receiver would provide for distribution of received signals to several main receiver units where simultaneous selection of several transmitted data channels may be required.

Although the detailed performance specifications contained herein do not constitute official Navy recommendations, they do represent the combined viewpoints of test-range personnel involved in telemetry instrumentation, government laboratory engineers engaged in development of missile instrumentation systems, guided missile designers responsible for internal instrumentation, and the design and development engineers of several manufacturers of telemetry transmitters and receivers.

Design Objectives for
Telemetry R-F Transmission Links
for the Period 1960 to 1970
(Second Revision)

UHF TELEMETRY TRANSMITTER

UHF TELEMETRY TRANSMITTER

This specification outlines the requirements for a basic UHF Telemetry Transmitter capable of operating in either the 1435- to 1535-Mc band or the 2200- to 2300-Mc band. The basic transmitter should be capable of handling FM/FM, PDM/FM, PAM/FM, and PCM/FM types of signals without design modifications, except that modular-type plug-in or replaceable modulator and power supply sections may be used as a means of accommodating any one of the various types of modulation or power input specified. Replaceable modular units, such as oven-stabilized, frequency-determining crystals or fixed-tuned reference cavities, may be used for selecting the desired operating channel frequency within the selected band. References to initial design objectives indicate requirements to be met prior to 1965. References to final, or ultimate, design objectives indicate requirements to be satisfied prior to 1970.

The application of the described transmitters will be essentially the same as that of the transmitters used today in the 215- to 260-Mc band. Present restrictions as to allowable space, weight, and input power apply to any new transmitters designed for use in the immediate future (12 to 24 months). However, ultimate designs may be further restricted and may require maximum use of solid-state components and subminiaturization techniques in order to achieve considerable reductions in the size and weight of missile-borne equipment. In general, if the system is to be useful, initial design objectives should restrict the size of the transmitter package (which includes the power supply) to a maximum of 100 cu in. Subsequent improvement should allow further reduction in volume to 50 cu in. or less, which will satisfy the space requirements of several programs. Eventually, a transmitter system requiring less than 6 cu in. of space (exclusive of power supply) will be required to fit the very limited space in some vehicles.

Individual circuit functions, such as power supply, modulator, driver, power amplifier, and frequency reference source, should be assembled in separate modular packages so that the transmitter system may in turn be assembled in several different configurations by placing individual units in different positions with respect to one another.

The basic transmitter must be capable of reliable performance in a missile environment. Unfortunately, there is no individual military specification available which presents in detail the environmental requirements to be met by equipment designed for general use in all missiles or in certain classes of missiles; however, present-day requirements set forth in individual missile specifications and/or applicable portions of Military Specification MIL-E-5272, entitled "Environmental Testing, Aeronautical and Associated Equipment, General Specification for," may be used as a general guide. Although reliable performance in a missile environment has been emphasized, the utilization of the basic transmitter for aircraft flight testing is also important. MIL-E-5272 will serve as a general guide to aircraft equipment environmental requirements.

The majority of applications require a basic R-F output power in the order of 2 to 3 watts, with higher power levels being supplied as needed by power amplifiers capable of producing 10 to 20 watts, or more, of R-F output power when driven by the basic transmitter.

The basic transmitter should be capable of operating from a separate battery pack, from a 400- or an 800-cps generator source, or from a 28-volt dc missile prime power source, when used with an appropriate power supply. In the interest of efficient utilization of space and available input power, it is considered appropriate to use a separate power supply design for each of the possible sources of input power.

Maximum use should be made of solid-state devices or special-purpose vacuum-tube devices in order to improve power efficiency and space utilization, provided reliability is not compromised.

The current version of IRIG Document Number 106-60, entitled "Telemetry Standards," and Military Specification MIL-I-26600 should be used as guides for R-F interference requirements of the airborne transmitter unit. The current version of MIL-E-8189, entitled "Electronic Equipment, Guided Missiles, General Specification for," may be used as a general guide for the selection of materials and components for the transmitter and its associated power supply. MIL-STD-810, "Military Standard Environmental Test Methods for Aerospace and Ground Equipment," may be used as a supplement to MIL-E-5272 for environmental requirements and methods of testing.

Specific performance requirements and physical limitations for the transmitter are tabulated in the section that follows.

PERFORMANCE CHARACTERISTICS

Frequency Range	1435 to 1535 Mc 2200 to 2300 Mc Each transmitter should be capable of operating throughout one or the other of the specified bands without design modifications.
Frequency Tolerance	Initial Design Objective (1965): The transmitter R-F carrier should remain within ±0.002% of the assigned carrier frequency for a ±250-kc deviation, and within ±0.005% of the assigned carrier frequency for a ±1.5-Mc deviation. Final Design Objective (1970): The transmitter R-F carrier should remain within ±0.001% of the assigned carrier frequency for a ±1.5-Mc deviation under all conditions, including specified changes in environment.
Power Output	Basic Transmitter: 2 to 3 watts output throughout the specified frequency range Associated Low-Power Amplifier: 5 to 10 watts output Associated Medium-Power Amplifier: 15 to 25 watts output Associated High-Power Amplifier: 40 watts and above for special applications
Load Impedance	50-ohm nominal The transmitter should not be damaged or its operation impaired, except for reduced output power, when operated with a load with a VSWR up to 5:1.
FM Deviation Capability	With respect to the signal input voltage to the modulator, linearity should be: 0.5% or better for ±250 kc deviation 1% or better for ±500 kc deviation 5% or better for ±1.5 Mc deviation

Amplitude Modulation

The amplitude modulation of the transmitter should not exceed 1% when subjected to the specified environment.

Interference

Spurious, harmonic, and fundamental signals conducted by power leads or radiated directly from equipment units or cables (except antennas) should be within the limits specified in current MIL-I-26600 specification and in IRIG Recommended Telemetry Frequency Utilization Parameters and Criteria for the 216-260, 1435-1535, and 2200-2300 Mc Bands (IRIG Document 106-60).

All spurious and harmonic outputs, antenna-conducted (i.e., measured in transmission line between transmitter output connector and load), should be at least 60 db down from the carrier.

Modulation

The transmitter should be capable of operating with FM/FM, PDM/FM, PAM/FM, or PCM/FM signals as specified by present IRIG Standards for Telemetry and subsequent revisions and additions thereto. True frequency modulation of the carrier is recommended; however, an alternate transmitter design providing phase modulation of the carrier would be acceptable for some applications.

Spurious Modulation

Incidental FM should be less than ±5 kc under all conditions.

Modulator

Input Impedance: Not less than 100 kohm shunted by no more than 20 μμf

Sensitivity: 1.0 volt rms or less to produce ±250-kc deviation

Frequency Response: Within 1 db from 20 cps to 800 kc, and not more than 3 db down at 1.2 Mc

The modulator may be a replaceable assembly or module. Although a frequency response of 20 cps to 1.2 Mc is specified for purposes of meeting the requirements of all four types of input signal, a 100-cps to 300-kc response would be adequate to meet the majority of applications in the near future. It is also possible that some applications of the basic transmitter will require a modulator with a frequency response down to dc, although such a requirement may considerably complicate the system. Premodulation filtering has not been specified as a required feature of the basic transmitter. However, a low-pass filter compatible with the specific type of modulating signal used will be required ahead of the modulator to reduce the skirts of the transmitted signal and to achieve a significant improvement in spectrum utilization.

Minimum Life Requirement — 1000 hours without necessity for any major repair, replacement, or adjustment

Warm-Up Time — The transmitter assembly should operate in accordance with specified performance within 120 sec after application of power.

Overall Efficiency — The power efficiency (Total Output Power vs. Total Input Power) should be as high as possible. Although not normally attainable at present, final designs should allow an overall power efficiency of not less than 20% for the basic transmitter and not less than 15% for the basic transmitter and associated electronic power supply, when operated together.

Power Supply — Separate power supplies should be used to adapt the basic transmitter or associated power amplifiers to a specified source of prime power. Provision should be made for the use of 28 ± 4 volts dc and 115 ± 12 volts, 350-850 cps ac, as well as separate battery packs for sources of operating power.

PHYSICAL LIMITATIONS

Volume — No design should be considered which requires more than 100 cu in. for a 2- to 3-watt transmitter, complete with power supply. A more useful system would be one which provides 2 to 3 watts of output power in a total package volume of 50 cu in. or less. The latter system would satisfy the space requirements of many Navy missile programs.

Dimensions — The individual modules, which constitute the transmitter in a 50-cu-in. system, should be designed for assembly in a configuration not exceeding 5.0 in. in length, 3.75 in. in width, and 3.0 in. in height. Individual modular units should be basically rectangular in cross section and should not exceed 5.0 in. in length, 2.5 in. in width, and 2.5 in. in height. The dimensions of individual modular units should be integral multiples of 0.25 in.

Uniformity of selected dimensions for length, width, and height will permit more effective use of total volume, and will provide more possible stacking combinations, thus allowing the modules to fit several different space configurations.

<u>R-F Output Connector</u>
MS coaxial

<u>Mounting</u>
Provision should be made for securing individual modules to a flat heat-sink surface by means of machine screws rather than clamps. All input and output connections should be confined to one surface of a given module, so as to allow stacking of modules without interference of connectors, cables, or wires.

<u>Weight</u>
The total weight of a 50-cu-in. transmitter assembly (or the total combined weights of individual modules) equipped for operation from either a 28-volt dc source or a 115-volt ac source should not exceed 8 lb.

<u>Cooling</u>
The design of individual modules should be such as to allow cooling by means of heat conduction to a heat sink. Modules should be so designed as to require contact with a heat sink on one surface only.

* * * * *

NOTE: The following environmental specifications are set forth for guidance purposes only. Individual applications of a transmitter may be such as to require operation under more stringent conditions, or they may be such as to allow relaxation of some requirements.

<u>Temperature and Altitude</u>
The transmitter assembly or any individual module should operate within specifications with any heat-

sink temperature between -40 and +85°C, and with any pressure corresponding to an altitude range of sea level to 75,000 ft.

Vibration

Each module of the transmitter should be capable of operating without degradation of performance below the minimum acceptable limits set forth in this specification at any vibration frequency from 45 to 2000 cps at an amplitude corresponding to 20 g in each of three mutually perpendicular axes. The displacement may be held at 0.2 in. double amplitude for vibration frequencies from 5 to 45 cps.

Sustained Acceleration

The transmitter should operate under conditions of sustained accelerations of 15 g in any direction for a period of 3 min without degradation of performance.

Shock

The transmitter should withstand a minimum of two impact shocks of 30 g with an 11-ms duration in both directions in each of three mutually perpendicular axes for a total of 12 impact shocks.

Acoustical Noise

The transmitter should operate within specified limits when exposed to an overall sound pressure level of 150 db above 0.0002 dyne/cm^2 in the frequency range of 75 to 9600 cps for 3 min.

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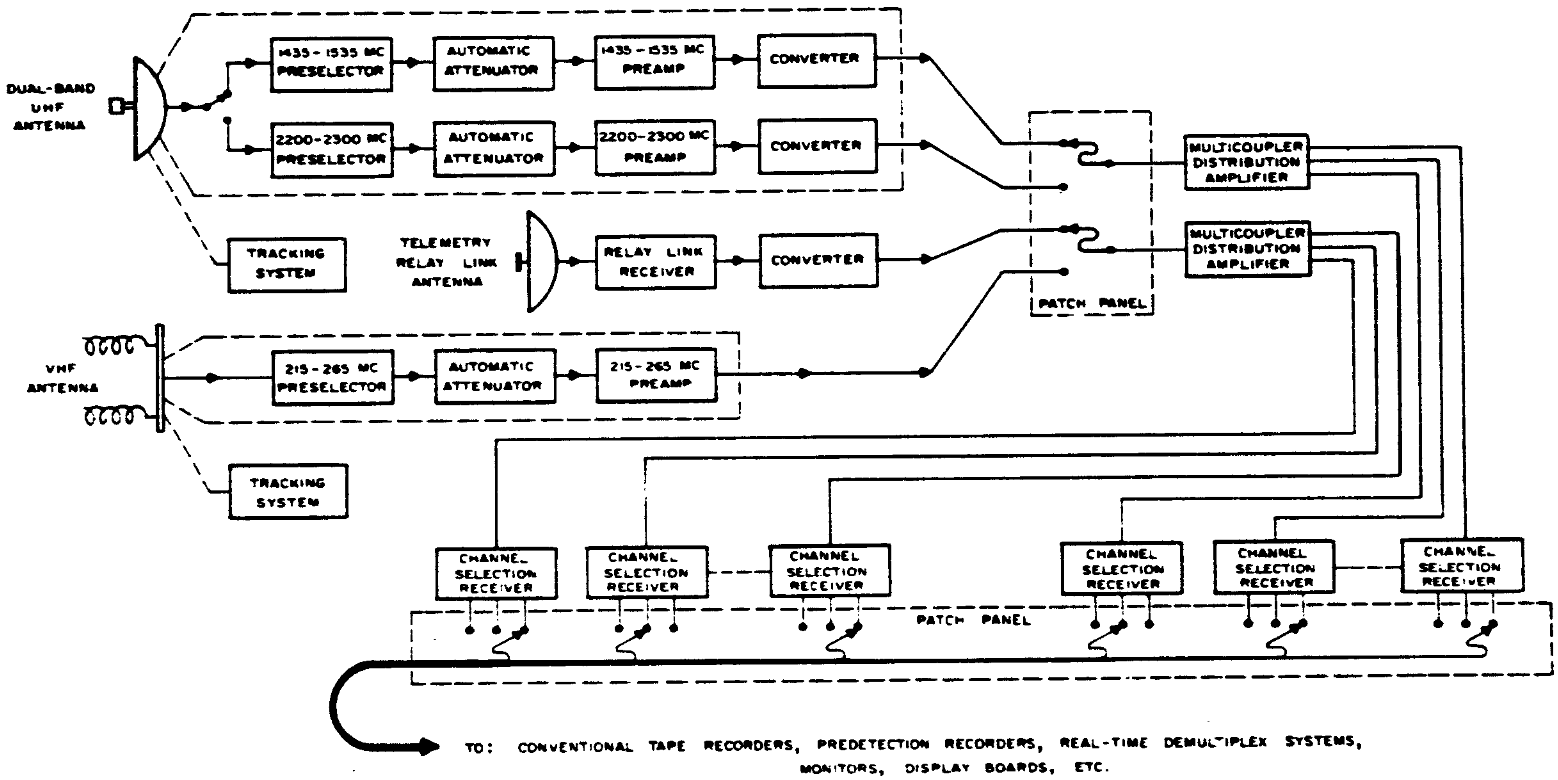
UHF TELEMETRY RECEIVER SYSTEM

UHF TELEMETRY RECEIVER SYSTEM

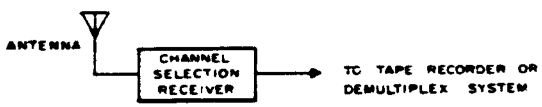
This specification outlines the requirements for a basic UHF Telemetry Receiver System capable of operating primarily in the 1435- to 1535-Mc band and in the 2200- to 2300-Mc band, with the additional capability of operating in other bands of 100 Mc or less in width, as required. The basic receiver should be designed for handling FM, PM, and AM signals which are modulated by FM, PDM, PAM or PCM formats. References to initial design objectives indicate requirements to be met prior to 1965. References to final, or ultimate, design objectives indicate requirements to be satisfied prior to 1970.

Use of such new devices as parametric, maser, or traveling-wave tube amplifiers offers considerable possibility for obtaining high-frequency telemetry receiver systems with improved sensitivity characteristics through reduction of front-end noise. If these devices are to be utilized to full advantage, however, it appears necessary to consider the receiver as made up of two major assemblies physically separated from each other. The receiver "preamplifier-converter," mounted as part of the receiving antenna, would consist of a low-noise amplifier, a frequency converter, and related components. The main receiver or "channel-selection receiver" would provide the necessary channel selection, amplification, bandwidth determination, and detection functions normally associated with a telemetry receiver. The use of a multicoupler or distribution amplifier between the receiver front-end and the main portion of the receiver would provide for distribution of received signals to several main receiver units for simultaneous selection of several transmitter channels. A block diagram of the suggested general-purpose receiver system is shown in Figure 1(a). It should be noted that the UHF Telemetry Receiver System described herein will allow the use of existing telemetry receivers (for the 215- to 260-Mc band) in place of the main receiver where the characteristics are adequate to meet the requirements of a particular program.

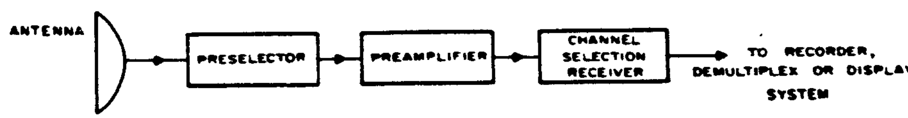
There are special-purpose receiving facilities—see Figure 1(b) and 1(c)—such as mobile telemetry vans and checkout systems which allow the channel-selection receiver to be located within a few feet of the receiving antenna. In such applications a preamplifier may be used ahead of the channel-selection receiver without the necessity of using a down-converter and distribution amplifier, provided the receiver is capable of tuning at the received signal frequency. In other applications, where high sensitivity and a low-noise receiver front-end are not important,



(a) TYPICAL MAIN TELEMETRY RECEIVING COMPLEX



(b) VHF OR UHF MONITOR STATION OR CHECKOUT SYSTEM



(c) VHF OR UHF LOW-NOISE MONITOR OR BACKUP RECEIVING/ RECORDING FACILITY

FIGURE 1. Block Diagrams of Typical Telemetry Receiving Facilities

the channel-selection receiver may be connected directly to a suitable antenna. The same basic channel-selection receiver that is proposed for use with a general-purpose receiving system may also be used to advantage in these special-purpose receiving facilities.

The versatility and application of the channel-selection receiver unit may be substantially increased by designing the tuning head or channel-selection portion of the receiver as a replaceable or plug-in assembly. Receiver tuning assemblies designed to cover the 215- to 315-Mc, 1435- to 1535-Mc, and 2200- to 2300-Mc bands would allow the main receiver to be used for at least three different basic applications:

1. Where a requirement exists for a self-contained receiver capable of operating with input signals in either of the assigned UHF telemetry bands, and a low-noise figure is not of prime importance, the channel-selection receiver could be used alone by selecting the appropriate UHF plug-in tuning assembly and connecting to a suitable antenna.

2. In a similar manner, the channel-selection receiver unit could be used as a self-contained VHF receiver for the present 215- to 260-Mc band by selecting the 215- to 315-Mc plug-in assembly and connecting to an appropriate antenna.

3. The channel-selection receiver, equipped with the 215- to 315-Mc tuning assembly, could also serve as the channel-selection portion of the low-noise general-purpose receiving system described previously.

The suggested approach to the design of the main receiver would allow its use for other than the presently assigned bands, if such a need should arise, by providing an additional channel-selection plug-in assembly to cover the appropriate frequency range.

The detailed performance specifications that follow consider the important requirements of the preamplifier-converter, multicoupler, and channel-selection receiver under separate headings. It is important that the design of the receiving system front-end be integrated into the design of the receiving antenna and its mounting. The environment to which the preamplifier-converter will be subjected will therefore be the same as that specified for the antenna. The current version of IRIG Document No. 106-60 on IRIG Telemetry Standards and the current version of MIL-I-26600 should be used as general guides to the requirements of the receiver system. The current version of MIL-E-16400, entitled "Military Specification, Electronic Equipment, Naval Ship and Shore," should be used as a general guide for the design and construction of the receiving system. Maximum utilization should be made of modular type construction to allow flexibility of receiver characteristics through interchange of assemblies such as I-F strips, detectors, filters, and other major circuit portions of the receiver.

PERFORMANCE CHARACTERISTICS

RECEIVER PREAMPLIFIER-CONVERTER

<u>Frequency Range</u>

1435 to 1535 Mc
2200 to 2300 Mc

Although the present requirements are restricted to these bands, future programs may require additional frequency utilization above 1000 Mc with bandwidths of 100 Mc or less. If utilization of the present 215- to 260-Mc band is required, and a low-noise system is desirable, the preamplifier-converter combination would be replaced by only a preamplifier unit with essentially the same characteristics (except for frequency range and bandwidth) as specified in this section for the preamplifier-converter.

<u>Source (Input) Impedance</u>

50-ohm nominal

<u>Load (Output) Impedance</u>

50-ohm nominal

<u>Noise Figure</u>

Initial Design Objective (1965): 4 db or less
Final Design Objective (1970): 2 db or less

The specified noise figure applies to the overall receiver system, i.e., preamplifier-converter (including preselector), distribution amplifier, and channel-selection receiver.

<u>Local Oscillator Stability</u>

Initial Design Objective (1965): ±0.001%
Final Design Objective (1970): ±0.0005%

The incidental FM of the local oscillator should be less than ±5 kc under all conditions, including environment.

Preselector

A preselector unit designed to reject signals outside the designated bands of 1435 to 1535 Mc or 2200 to 2300 Mc should be provided ahead of the preamplifier in order to prevent unwanted signals at the antenna output termination from causing nonlinear operation of the preamplifier. The insertion loss in the pass band of the preselector should be held to a minimum and should in no case exceed 1.0 db in an initial design or 0.5 db in a final design. The ripple in the pass-band characteristic should not exceed 1.0 db in an initial design or 0.5 db in a final design. The minimum attenuation for frequencies from dc to 0.98 times the lower cutoff frequency should be 60 db. The minimum attenuation for frequencies from 1.02 times the upper cutoff frequency to 10 times the upper cutoff frequency should be 60 db. The preselector should normally provide a pass band of 100 Mc as measured at the 1-db points; however, some applications may require that the pass band be reduced to 10 Mc at the 3-db points. Therefore, the preselector should be tunable to allow for adjustment of the bandwidth and center frequency. Shipboard installations or systems operating in an area near other tracking or communications equipment may require rejection-type filters in addition to the band-pass filter in order to minimize interference from specific high-power equipments located in close proximity to the telemetry receiving antenna.

A rejection filter should in no case add more than 0.5 db of additional attenuation to any signal that is more than 15 Mc away from the center frequency to which the rejection filter is tuned. Rejection filters should be continuously tunable over the frequency range from 1250 to 1750 Mc or from 1900 to 2600 Mc, and should provide an additional attenuation of at least 30 db for a bandwidth not to exceed 5 Mc. Provision should be made for remote tuning and monitoring of both band-pass and rejection characteristics of the preselector unit.

Attenuator

It is required that the receiving system be capable of linear operation with signal amplitudes up to 0.1 volt rms. If signal amplitudes of less than 0.1 volt cause overloading, generation of spurious responses, or other forms of nonlinear operation when the AGC circuits are operating, an automatic attenuator should be provided ahead of the preamplifier to prevent high-level signals within the pass band from causing nonlinear operation.

The attenuator, if required, should be a maintenance-free device, preferably of the type using ferrite or YIG materials which provide minimum attenuation of low-level signals and at the same time limit high-level signals to reasonable levels. The minimum insertion loss should be 0 db, although insertion losses as high as 0.3 db could be tolerated.

Image Rejection — Greater than 60 db

Gain — The preamplifier-converter combination should provide a minimum overall gain of 25 db in the pass band. The gain should have a response uniformity of 3 db or better across the pass band. If AGC voltages are used to control the gain of the preamplifier-converter unit, the minimum gain requirement may be satisfied with the AGC circuitry disabled.

Output — The preamplifier-converter combination should be a wide-band device capable of providing a full 100-Mc bandwidth centered at 265 Mc. Selection of any particular assigned channel between 215 and 315 Mc will be accomplished by one or more channel-selection receiver units to be located away from the preamplifier-converter. The output impedance should be 50-ohm nominal.

Output Connector — MS coaxial

Power Supply — Self-contained and regulated to the degree required for specified stability, 117 volts ± 10%, 50-450 cps ac input

Housing — The entire preamplifier-converter assembly, including the preselector, should be mounted in a sealed, weatherproof housing that may be readily opened when required for maintenance or periodic adjustment. However, the design should be such as to minimize the necessity for adjustment or replacement of components. Electrical or other appropriate heating may be utilized to control the minimum operating temperature within the assembly housing.

DISTRIBUTION AMPLIFIER

A distribution amplifier should be made available as an optional equipment suitable for use in connecting a number of channel-selection receiver units to a single preamplifier-converter unit. The preamplifier-converter may be located up to 200 ft away from the distribution amplifier, and the receivers may be located up to 100 ft away from the distribution amplifier. The receiving system should be capable of optimum performance without the use of the distribution amplifier where relatively short runs (less than 50 ft) of cable are required and a single channel-selection receiver is to be used.

Pass Band	215 to 315 Mc
Uniformity of Response	Within 2 db
Gain	The minimum overall gain should be sufficient to maintain the system noise figure at the level determined by the preamplifier-converter under the conditions where the longest lengths of cable are used. The gain of the distribution amplifier should be adjustable in 2-db steps or continuously adjustable to minimize the possibility of overloading the receiver units that may be connected to the amplifier.
Input Impedance	50-ohm nominal
Output Impedance	50-ohm nominal
Number of Outputs	Provision should be made for separate connection of up to 8 channel-selection receiver units
Output Connector	MS coaxial
Isolation	40-db minimum isolation between outputs 70-db minimum isolation between any output and the input
Power Supply	Self-contained; requires input of 117 volts ± 10%, 50-450 cps ac

Mounting	The distribution amplifier should be designed to mount in a standard 19-in. cabinet rack for the majority of applications.

CHANNEL-SELECTION RECEIVER

The channel-selection receiver should be designed for use as a separate VHF-UHF telemetry receiver or for use as the channel-selection portion of a general-purpose telemetry receiving system. Maximum utilization should be made of modular-type construction to allow the basic receiver to be used for several applications by replacing one or more plug-in or replaceable subassemblies. The design should allow for changing—by replacement of appropriate subassemblies—the input operating-frequency range, the I-F bandwidth, the type of demodulator, and the video bandwidth characteristic of the receiver. The plug-in subassemblies should be accessible from the front panel of the receiver.

Frequency Tuning Range	215-315, 1435-1535, and 2200-2300 Mc, by selection of appropriate replaceable tuning head
Type of Input Signal	FM, PM, and AM signals that are modulated by FM, PDM, PAM, or PCM formats, as detailed in IRIG Document 106-60
Input Impedance	50-ohm nominal
Noise Figure	When the channel-selection receiver is used as a separate self-contained unit, the noise figure should not exceed 7 db for the 215- to 315-Mc band, or 9 db for either the 1435- to 1535-Mc band or the 2200- to 2300-Mc band. The system noise figure is specified in the preceding section, "Receiver Preamplifier-Converter."
Preselector	The input to the channel-selection receiver should be through an R-F preselector filter. The filter should be a continuously tunable subassembly provided with front-panel controls and calibrated dial. It should be included as part of a replaceable tuning-head assembly. (Substantial improvement in the front-end selectivity characteristics of the receiver over and above that normally obtained in present-day VHF receivers is considered necessary.) The preselector is required to minimize adjacent channel and image interference, and it should provide

for a maximum 3-db bandwidth of 10 Mc as an initial design objective.

The cutoff characteristics of the preselector should be the best possible commensurate with the state of the art. For all bands, the bandwidth at the 60-db points should be no greater than seven times the bandwidth at the 3-db points.

I-F Rejection	Greater than 80 db
Image Rejection	Greater than 60 db
Spurious Response	All frequencies outside the tuning range of the receiver, other than those noted under "I-F Rejection" and "Image Rejection" of this section, should be rejected in accordance with the requirements set forth in Section 4.3.4.4 of MIL-I-26600, provided that no signal with an amplitude greater than 0.2 volt rms is applied to the input terminals of the channel-selection receiver.
First Local Oscillator	Selectable from front panel: 1. Crystal-controlled oscillator with a stability of ±0.0005% 2. Continuously tunable oscillator, temperature-compensated for a stability of at least ±0.001% per degree centigrade, for all bands NOTE: The provision for use of either a crystal-controlled or a continuously tunable local oscillator may be satisfied by providing individual front-panel plug-in subassemblies for the R-F tuning heads.
Second Local Oscillator	Tunable over a range of ±250 kc, with front-panel control, temperature-compensated for maximum stability
I-F Bandwidth	The bandwidth should be 12.5,* 25,* 50,* 100, 300, and 500 kc, and 1.0** and 1.5** Mc, as measured at the 3-db points. At the 60-db points, the bandwidth

*For use in special applications in VHF band.

**For use in UHF bands.

should be no greater than 2.4 times the bandwidth at the 3-db points. The basic bandwidth of the I-F amplifier should be at least 2 Mc without filters. The center frequency of the I-F pass band, including the effects of I-F plug-in filter, amplifier, and demodulator, should be stable to within ±0.1% of design center frequency.

Limiting

Limiting should be considered as taking place when a 10% change in signal input amplitude does not cause more than a 1% change in signal amplitude at the output terminals of the last limiter stage. Limiting should occur with a signal level (unmodulated carrier) no greater than 5 μv rms applied to the input terminals of the channel-selection receiver. The limiter circuitry should be such as to produce less than 0.5% change in video output level with 50% amplitude modulation of a carrier by frequencies from 10 cps to 1.5 Mc.

Demodulators

Plug-in or replaceable demodulator units are recommended. Provision should be made for the following, as a minimum:

1. FM Discriminator: Linearity should be 0.5% or better over a ±250-kc bandwidth, 1% or better over a ±500-kc bandwidth, and 5% or better over a ±1.5-Mc bandwidth.

2. AM Detector: Provision should be made for an amplitude modulation detector connected ahead of the limiter stages. Sufficient isolation should be provided to insure that any loading of the AM output terminals will cause no change in the characteristics of the I-F amplifier. The AM detector should provide a minimum frequency response of 10 cps to 100 kc, with no greater than 2% total distortion. A separate output stage capable of furnishing 2 volts peak-to-peak across a 200-ohm load shunted by 1800 μμf should be provided for the demodulated AM signal.

3. Other Detectors: Other demodulators, such as phase-lock detectors, product detectors, and synchronous detectors, should be accommodated by the use of plug-in modules. Adequate space should be provided for mounting a phase-lock-

detector module by means of a connector. Additional types of special detectors should be modular assemblies which are electrically and mechanically interchangeable with the phase-lock-detector module.

Automatic Gain Control (AGC)

Provision should be made for automatic control of the overall gain of that portion of the receiver preceding the limiter. The AGC circuitry should be so designed that input signals of 5 μv to 0.2 volt rms will cause no more than a 7-db variation in output level as measured at the AM detector, and no more than a 2-db variation as measured at the output of the FM discriminator. With 0.2 volt rms input signal, amplitude-modulated 30% with 1000 cps, the distortion as measured at the output of the AM detector should not exceed 5%. Provision should be made for varying the time constant of the AGC circuitry and disabling the AGC by means of a switch on the front panel. The switch will provide for time constants of 500, 50, and 5 ms, two blank positions, and a position for "AGC OFF" or "MANUAL." Disabling the AGC should not cause detuning of the I-F amplifiers.

Automatic Frequency Control (AFC)

Provision should be made for automatic frequency control of the receiver, to allow for drift in transmitter frequency. Acquisition range of the AFC circuit should be at least ±50% of I-F bandwidth. Retention range should cover the acquisition range with no greater error than ±500 cps for each 100 kc of drift. Drift rates up to 250 kc/sec^2, occurring for no longer than 3 sec, should cause no error greater than ±2.5 kc. The requirements previously stated for AFC acquisition and retention should be met with a minimum limiting signal, as specified under "Limiting" of this specification. Provision should be made for disabling the AFC by means of a front-panel control. Provision should also be made for gated AFC operation with PAM/FM and PCM/FM signals. The triggering pulse for actuating the gating circuitry will be provided external to the receiver by other equipment, as required.

Video Bandwidth

The basic video amplifier should have a minimum frequency response of 10 cps to 1.5 Mc, as measured at the 3-db points. Provision should be made for limiting the overall video response characteristic by means of low-pass filters following the carrier discriminator. Gaussian or maximally linear phase-response filters with a slope of 36 db/octave should be provided for cutoff frequencies of 6.25, 12.5, 25, 50, 100, 200, and 400 kc. It should be noted, however, that some applications may require Butterworth or constant amplitude response filters which cover the same range of cutoff frequencies.

Provision should also be made to allow the video amplifier to be connected directly to the carrier discriminator. The video bandwidth selection may be made by means of a selector switch or by replacement of a plug-in assembly. Because other than the listed bandwidths may be required in future applications, individual filters should be plug-in or replaceable units, to allow for use of additional cutoff frequencies.

Video Output Level

For any full-scale deviation between ±100 kc and ±1 Mc at the discriminator, the video amplifier should be capable of providing a minimum signal of 1 volt rms when matched to a 50-ohm load, and 10 volts to a 5000-ohm load shunted by 1800 μμf. The frequency response of the video amplifier for the 50-ohm output should be 10 cps to 1.5 Mc, as measured at the 3-db points. However, the frequency response at the 5000-ohm output may be limited to 10 cps to 0.15 Mc, as measured at the 3-db points. Provision should be made for setting the output level by means of a variable front-panel control used in conjunction with the video output level meter.

Power Supply

Self-contained and regulated to the degree required for specified stability, 117 volts ±10%, 50-450 cps ac input. Individual circuits should be so designed as to require no more than 1% regulation of any supply voltage.

Special Features

The receiver should include the following special features:

1. Frequency Deviation: Multiscale meter with 25, 75, 150, 500, and 1500 kc (peak) full-scale

ranges and ±10% accuracy for any single modulating frequency

2. Signal-Strength Indicator: Multiscale meter to provide 1000 μv and 100,000 μv full scale with ±10% accuracy

3. Tuning Indicator: Meter calibrated for plus and minus deviation from center of discriminator characteristic

4. Video Output Level: Meter calibrated in volts rms or in any other applicable units

5. AGC Output: Provision for supplying isolated AGC voltage to external 10-kohm load shunted by 1000 μμf

6. Spectrum Analyzer Output: Provision for connecting a typical high-resolution commercial spectrum display unit with a 50-ohm input impedance into the I-F circuitry

7. Antenna Tracking Signal Output: Provision for use of last I-F signal ahead of limiters for antenna tracking equipment

8. Predetection Recording Outputs: Provision for use of I-F signal ahead of as well as after the limiters, but ahead of the discriminator for predetection recording purposes

9. Predetection Recording Input: Provision for inserting predetection recorded signals into last I-F amplifier, ahead of the limiters

10. Signal Strength Recorder Output: Provision for supplying 0-10 volts into 600-ohm load, with output range adjustable by semifixed control

11. Audio Monitor Output: Provision for self-contained audio monitor speaker with adjustable level control, and for adjustable audio output to provide at least 1 volt rms into 1000-ohm load for headset monitor.

Space Requirements

The receiver should be packaged to fit standard 19-in. cabinet-rack configurations. Special installations may require a miniaturized version of the channel-selection receiver designed to fit existing mounting cabinets.

Environmental Requirements

The receiver should be designed to meet the requirements for Class 4 equipment as specified in MIL-E-16400.

Design Objectives for
Telemetry R-F Transmission Links
for the Period 1960 to 1970
(Second Revision)

UHF TELEMETRY RECEIVING ANTENNA

UHF TELEMETRY RECEIVING ANTENNA

This specification outlines the requirements for a basic UHF Telemetry Receiving Antenna for use primarily in the 1435- to 1535-Mc and 2200- to 2300-Mc bands.

As the performance requirements for a receiving antenna may vary considerably from program to program or from test range to test range, no attempt is made in these specifications to cover all possible applications. The specification does, however, outline the requirements for a receiving antenna system that should fulfill the needs of the majority of users as envisioned at present. Many possible antenna configurations using parabolic reflectors, multiple helix arrays, horns, rod and disc elements, and other components are adaptable to the telemetry frequencies.

The high-gain narrow-beam-width requirement makes it necessary to provide target acquisition and tracking capability as part of the antenna system. In addition, the antenna system should be capable of providing full hemispherical coverage.

It is particularly important that the design of the receiving antenna be integrated with the design of the receiver front-end, and that provisions be made for mounting the receiver preamplifier-converter on the antenna pedestal.

The current version of IRIG Document 106-60 on Telemetry Standards and the current versions of military specifications MIL-I-26600 and MIL-E-16400 should be used as general guides to the requirements of the antenna system.

Detailed requirements of the receiving antenna system, insofar as they may be specified, are listed in the section that follows.

PERFORMANCE CHARACTERISTICS

Frequency Range — 1435 to 1535 Mc
2200 to 2300 Mc

Although the present requirements are restricted to these bands, future programs may require additional frequency utilization above 1000 Mc with bandwidths of 100 Mc or less.

Form

No specific form of array is specified, although consideration should be given to the use of parabolic reflector, helix, horn, rod and disc, and other possible devices for forming the required beam pattern.

Beam Pattern

Conical, with an axial ratio of 1 db or less

Beam Width

As the beam-width requirements may vary from installation to installation or program to program, it is desirable that the basic antenna design allow selection of beam-width characteristics within the following limits: 20 to 60 deg at 1485 Mc or 15 to 45 deg at 2250 Mc for target acquisition, and 6 to 27 deg at 1485 Mc or 4 to 18 deg at 2250 Mc for target-tracking applications when dual-beam arrays are used. Beam width may be determined by choice of dish size where parabolic reflectors are used or by choice of number and interconnection of elements where multiple-element arrays are used. An automatic means should be provided for selecting a wide beam width for target acquisition or a narrow beam width for target tracking when dual-beam arrays are employed.

Where scanning or lobing techniques are used for acquisition and tracking of a target, the requirements previously stated for beam width may be satisfied by selecting the scanning pattern to produce an effective beam width within the limitations specified for target acquisition and tracking. However, the additional requirements set forth under "Target Acquisition and Tracking" in this section of the report must also be satisfied.

Gain

10 db minimum for 50 deg beam width at 1485 Mc
28 db minimum for 6 deg beam width at 1485 Mc
12 db minimum for 40 deg beam width at 2250 Mc
32 db minimum for 4 deg beam width at 2250 Mc
(Gains are specified in db above an isotropic radiator.)

The antenna gain should be as high as possible commensurate with the limitations imposed by the required beam width. Where dissimilar polarization exists between transmitting and receiving antennas, the minimum gain may be 3 db less than tabulated above. The gain should be uniform within 3 db across the required 100-Mc bandwidth.

Polarization

The basic antenna should be circularly polarized. Special applications may require either right- or left-hand circular polarization in addition to horizontal or vertical polarization, indicating the desirability for developing an antenna that is not polarity sensitive. However, various polarizations may be accommodated by using interchangeable feed systems or a 3-axis antenna mount in conjunction with automatic correction for polarization changes.

Feed Impedance

50-ohm nominal

The specified feed impedance could depart from the stated value if the design were compatible with the requirements of the receiver preamplifier.

VSWR

1.3 maximum, over the required 100-Mc band

Side-Lobe Limitations

Side lobes should be 25 db or more below the level at the center of the main (narrow) beam.

Front-to-Back Ratio

As high as possible. The back lobe should be 35 db or more below the level at the center of the main (narrow) beam.

Target Acquisition and Tracking

Horizontal: Continuous rotation for azimuth tracking

Vertical: Full 180 deg minimum elevation tracking

Provision should be made for target acquisition and tracking. Although no specific method is indicated for acquiring and tracking a desired target, consideration should be given to the several techniques in use today in radar and other tracking systems. In many applications the telemetry receiving system will have to generate its own directional information for target-acquisition and tracking by use of scanning techniques, diversity comparison, or other means.

The basic antenna should be capable of providing a wide beam width with reduced gain for use near the launching point of a missile. Automatic switchover to a narrow-beam, high-gain configuration should be provided for use after target-acquisition phases are completed.

Multiple reflectors, dual feeds, scanning techniques, or other means may be used for providing the dual-beam capability. Down-range receiving stations may also use to advantage a dual-beam-width capability where passage of the target in the vicinity of the receiving station may be so rapid as to make narrow-beam tracking difficult. Use of the basic receiving antenna at down-range receiving locations will require the antenna assembly to be capable of tracking a target from horizon to horizon through the zenith.

In some applications, tracking information may be supplied by a radar system to which the telemetry antenna will be slaved. Provision should also be made for using the antenna in an aided tracking system.

The telemetry signal output from the antenna system should vary as little as possible during the tracking phase of operation. In an ultimate design, the telemetry signal output at the antenna terminals should vary by no more than 1.5 db during the tracking of a constant signal source.

Tracking Rates

Maximum practical tracking rates may be limited by the size and weight of each particular antenna structure; however, pedestal mounts, radiating structures, and drive mechanisms should be designed to allow tracking rates of 60 deg/sec in both azimuth and elevation as a minimum for a structure 12 ft in diameter, and a proportionately higher tracking-rate capability for assemblies of less than 12-ft diameter.

Physical Limitations

The majority of applications will be such as to limit the maximum dimensions of the basic reflector to a 12-ft diameter. Where parabolic reflectors are to be used, the antenna pedestal should be designed to accommodate reflective surfaces of 6-, 8-, 10-, and 12-ft diameters. Other types of arrays may allow for beam-width adjustment by replacing or changing the connections between the active and parasitic elements associated with the array.

Special Requirements

A special version of the basic receiving antenna will have to be designed for shipboard installations to provide a lightweight pedestal mount and an antenna array with a maximum diameter of 4 ft. The gain should be as high as possible commensurate with limitations in size, and in no case should the gain be less than 20 db at 1485 Mc or 24 db at 2250 Mc. (Gains are specified as db above an isotropic radiator.) In this application, the beam width may be fixed if the effective beam width is not less than 20 deg at 1485 Mc or 15 deg at 2250 Mc. The antenna mount should provide for continuous rotation in azimuth and positioning from 10 deg below horizontal to 110 deg above horizontal in elevation. Provision should also be made for applying roll and pitch correction to the positioning-control circuitry.

Other requirements will be essentially the same as those specified for the basic antenna.

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This report supersedes NAVWEPS Report 7202, dated 15 October 1961, on the same subject.

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2. Ultra high frequency transmitters—Design
3. Ultra high frequency receivers—Design
4. Telemetering antennas—Design

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