# Microwave Radio Equipment and Building Considerations

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*This paper points out salient equipment and building considerations peculiar to the TD-3 radio system and in particular emphasizes the important differences in station design that exist for TD-3 compared with TD-2 radio.*

## I. INTRODUCTION

Microwave radio relay stations have existed in the Bell System in several forms since 1950.[1] In this time, the equipment and the layouts within the buildings have changed to accommodate the new designs that have been introduced into these systems.

The introduction of the TD-3 repeater bay offers further opportunities for improvements particularly in the simplification of power requirements. The basic power for a TD-3 station is −24 volts dc. Those power plant elements peculiar to TD-2, namely the +250, +130, and −12V dc plants have been eliminated. Voltages other than −24V dc are furnished by dc-to-dc converters, except for +24V dc which may be furnished by a separate plant in some stations.

Except for the power plant, the typical TD-3 station will not differ greatly from recently constructed TD-2 stations, since the 100A IF protection switching system,[2] the 3A FM terminals, and the 3A solid-state wire line entrance links have been previously introduced into the TD-2 system. The 200A protection switching system for use with the 3A FM terminals and wire line entrance links has been developed for long haul microwave radio systems.

## II. TYPES OF STATIONS

There are two general types of TD radio stations: main radio stations and radio repeater stations. Main stations may be end points or intermediate points in the system where signals are accepted from and delivered to terminal facilities. In addition, main stations provide points of flexibility in the system for facilities such as IF patching and monitoring, automatic protection switching, dropping or picking up local or spur radio signals and maintenance switching from regular to protection channels. Such stations also are convenient locations for performing system tests and may include baseband multiplexing equipment. Main stations may be partially or fully attended.

The radio repeater stations provide transmission gain and maintain line-of-sight paths. They comprise the majority of the stations in any large system and are normally unattended. Unlike main stations, the repeater stations are quite uniform in their makeup and are more adaptable to standardized floor plans and building construction.

## III. MICROWAVE EQUIPMENT

The general design concept for all TD-3 equipment is to provide, insofar as practical, for assembly, wiring and testing of complete bays in the manufacturing shop. This results in a reduction of job engineering, installation, and field testing effort. For convenience and speed in restoration of service in the event of failure and, to reduce routine maintenance effort, extensive use is made of plug-in units which are carried as spare parts in the stations and at centralized maintenance repair centers. The major equipment required in a radio station is listed in Table I.

The microwave transmitters, receivers, and associated equipment in the radio room are mounted on 9-foot unequal flange, duct-type frameworks (see Fig. 1). This applies in general to all items except power plants which are mounted on 7-foot frames. The transmitter-receiver bays require only front access for maintenance and may be mounted against a wall or back-to-back with other bays. In general, the remaining equipment requires front and rear access. The color scheme in a TD-3 station is light gray with border items such as guard rails and end guards in a contrasting darker blue gray color. The superstructure with cable rack is just above the tops of the frames. Indoor waveguide arrangements are similar to TD-2 and, as in the latest versions of TD-2, use close tolerance flanges to assure a return loss of at least 40 dB.

Use has been made of a short piece of flexible waveguide to connect between the dropping networks of adjacent bays thus insuring a better connection and less possibility of RF leakage. This also simplifies to a considerable extent installer effort in accurate alignment

TABLE I—MAJOR EQUIPMENT IN A RADIO STATION

| Unit | Station | |
|---|---|---|
| | Main | Repeater |
| 1. Transmitter-receiver bay | Maximum of 12 for each route direction | Maximum of 24 for a through route |
| 2. Transmitter-receiver auxiliary channel* | One for each route direction | Maximum of 2 for a through route |
| 3. Multiplex equipment to derive voice circuits on auxiliary channels | X | X |
| 4. C1 alarm and order circuit equipment | Maximum 7 bays (21 scans—882 alarms and or indications and 490 orders) | Maximum 2 bays (3 scans) for most stations |
| 5. 100A protection switching equipment | 3 bays for each route direction | Maximum 2 bays if required to protect dropped channels |
| 6. IF patch and access | One bay provides for a maximum of 12 2-way radio channels in each of four directions | — |
| 7. 3A FM terminals and FM terminal patching | 1 bay for each 4 pairs of transmitters and receivers | As required for drop or pickup |
| 8. 200A FM terminal and wire line entrance link protection switching | Approximately 3 bays in the radio room and 2 bays in the multiplex area for each 1 × 12 switching system | — |
| 9. IF restoration | X | — |
| 10. IF and baseband monitoring | 1 bay | — |
| 11. Test equipment and spare parts | X | X |
| 12. Dehydrator for dry air supply to antenna system and to the transmitter-receiver bays | 1 or more as required | 1 for average station |

* This channel is used to provide order wire service, and to carry control tones for IF protection switching and alarm systems. Alternatively, wire lines may be used instead of the auxiliary radio channel.

| Unit | Station | |
|---|---|---|
| | Main | Repeater |
| 13. Tower obstruction light controls | X | X |
| 14. AC power distribution | X | X |
| 15. Engine alternator plant | X | X |
| 16. 111A −24 volt power plant | X | X |
| 17. −24 volt battery | X | X |
| 18. 111A +24 volt power plant and associated battery | X | If required |
| 19. 24 volt battery distribution circuit breaker board | Two | One |
| 20. Heating and air conditioning equipment | X | X |
| 21. Antennas and associated waveguide | X | X |

X = as required.

of bays which was required in initial TD-2 systems when hard waveguide fittings were used.

Attention is given to isolation of particularly noisy leads on the cable racks to reduce noise interference problems. This is accomplished by segregating such leads in metallic duct, thin walled conduit, or assigning such leads to dedicated cable racks or runs. Power leads to high-transient producing loads such as dc-to-dc converters come under this classification.

In addition to the above, leads carrying control signals between radio bays and units, such as alarm bays, are paired or looped insofar as practical to minimize noise problems. This also applies to power leads.

## IV. FLOOR PLANS

Figure 2 is a block schematic diagram of a main station complex with two-way radio channels in each of four directions. This figure illustrates the most efficient arrangement of equipment for a main station with the 70 MHz IF patch and access bay, shown as an octagon, as the focal point of the office. If the equipment could be laid out in this manner, the IF cable lengths would be minimized. Reducing cable length reduces the cross modulation noise resulting from echoes and facilitates the program to standardize IF levels in the radio station.

The typical floor plan (Fig. 3) shows a similarity to the ideal ar-

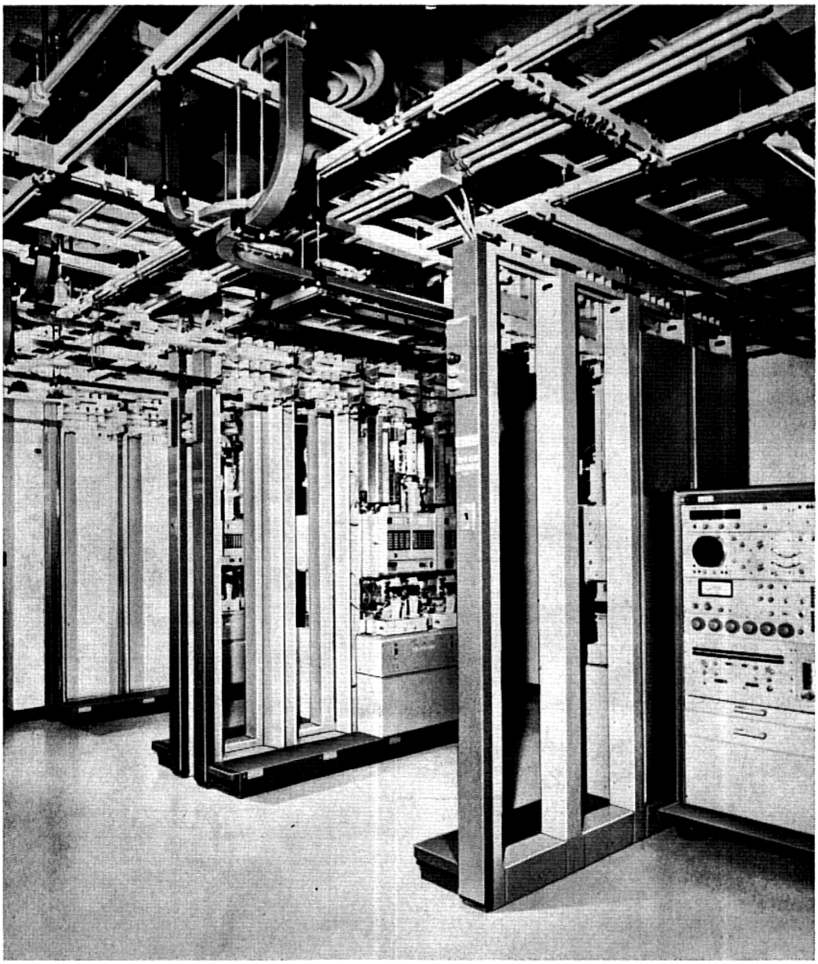

Fig. 1 — Microwave radio equipment bays in a station lineup.

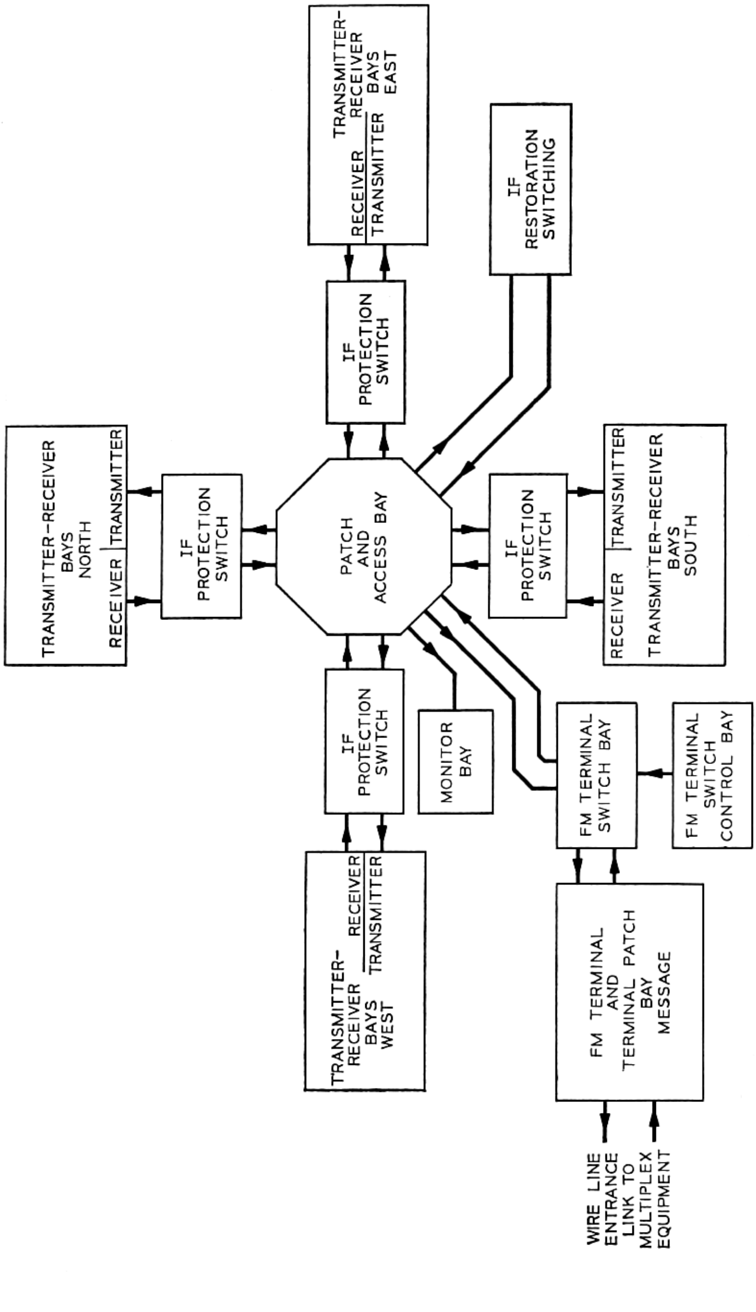


Fig. 2 — Typical block diagram of a TD-3 main station.

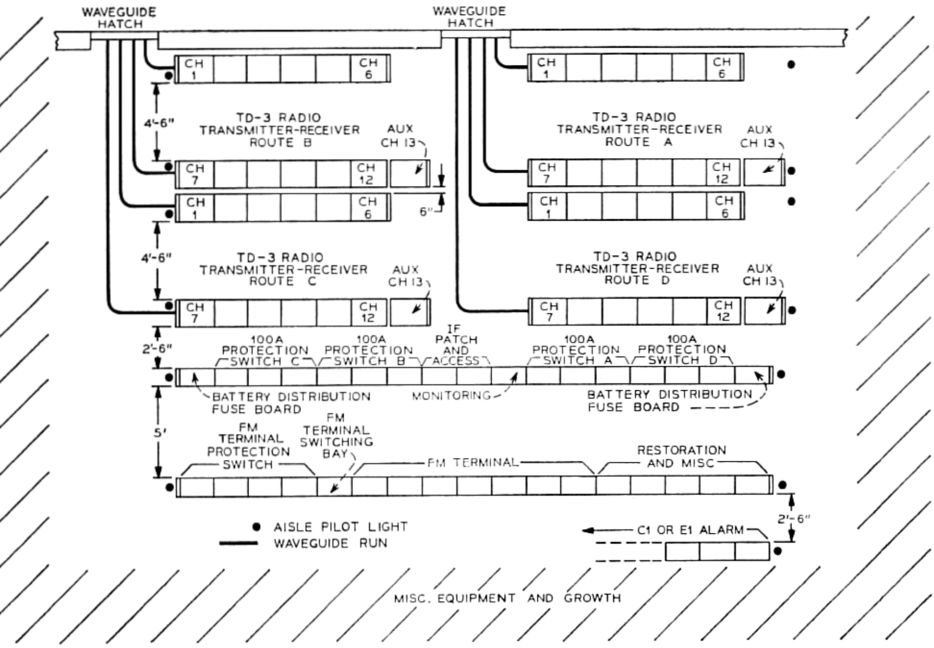


Fig. 3 — Typical main station equipment layout.

rangement of Fig. 2. The IF patch and access bay is centrally located and the other equipment is located so as to minimize the lengths of IF cables and thus approach the ideal as far as practical. The location of the transmitter-receiver bays and the use of two waveguide hatches, as depicted in Fig. 3, minimizes the length of the inside antenna waveguide. Figure 4 shows the layout for a repeater station. In this case there are no IF cabling problems since each transmitter-receiver bay is internally connected as a through circuit. The floor plans in Figs. 3 and 4 are typical of new stations now being engineered. Figures 5 and 6 are floor plans for main and repeater stations, respectively, used on the Arkansas-Mississippi trial. The primary consideration in these layouts is the placement of the transmitter-receiver bays in the strategic area directly under the tower in order to minimize the length of the waveguide runs.

## V. PATCH AND ACCESS BAY

The IF patch and access bay (see Figs. 7 and 8) has jack fields for terminating the inputs and outputs of radio channels (both regular

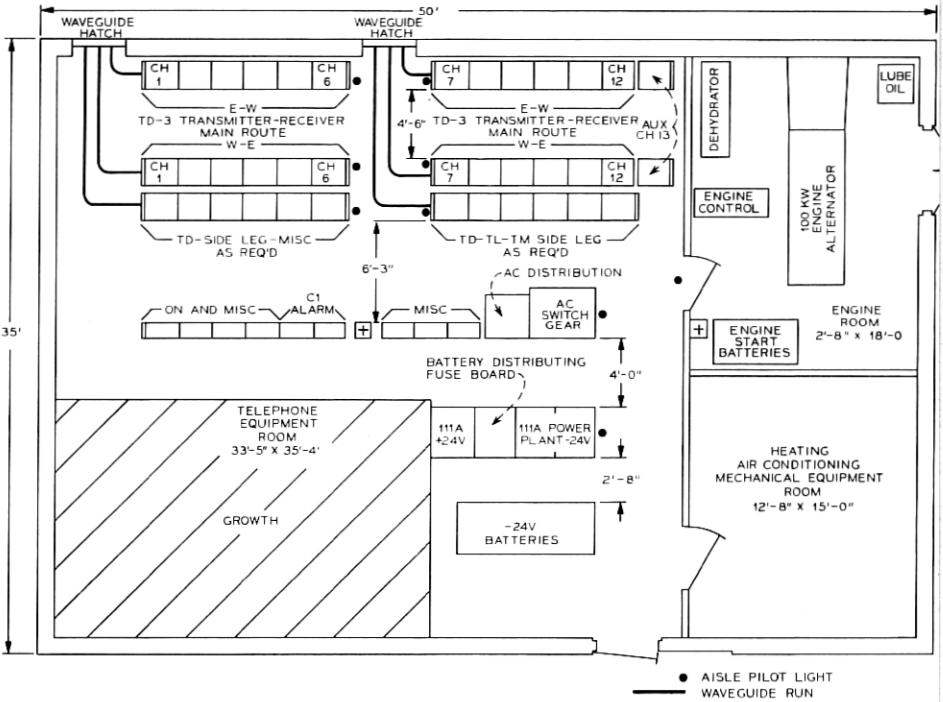


Fig. 4 — Typical repeater station equipment layout.

and protection) for flexibility and for maintenance and testing. This bay can be considered as a hub which interconnects the IF cabling from the protection switching bays, FM terminal patch bays, monitoring bays, restoration bays, and so on. The IF patch and access bays contain jack mountings for twelve incoming and twelve outgoing channels with their associated monitoring taps for four directions of transmission. The channels appearing in this bay may also be connected to reed type coaxial switches and coaxial type directional couplers for connecting through restoration equipment associated with FM terminal facilities or they may be connected through to trunks directly associated with FM terminal equipment. Since not all incoming circuits require switches and directional couplers, this bay has been designed to have a maximum capacity for 36 switches and couplers.

A revision of the monitoring bay is being developed to be associated with the patch and access bay. This monitoring bay will include a 3A FM terminal receiver to reduce IF signals to baseband, a de-emphasis network to compensate for the preemphasis of the signal at the originating terminal, an IF amplifier to compensate for the inherent loss of a monitoring tap, and a video monitoring amplifier and an "A" scope for visual observation of the signal. Facilities for local and express order circuits will also be included.

### VI. ALARMS AND MAINTENANCE ORDER CIRCUITS

The individual audible and visible alarm equipment in TD-3 offices are decentralized with the individual alarm relay circuits located

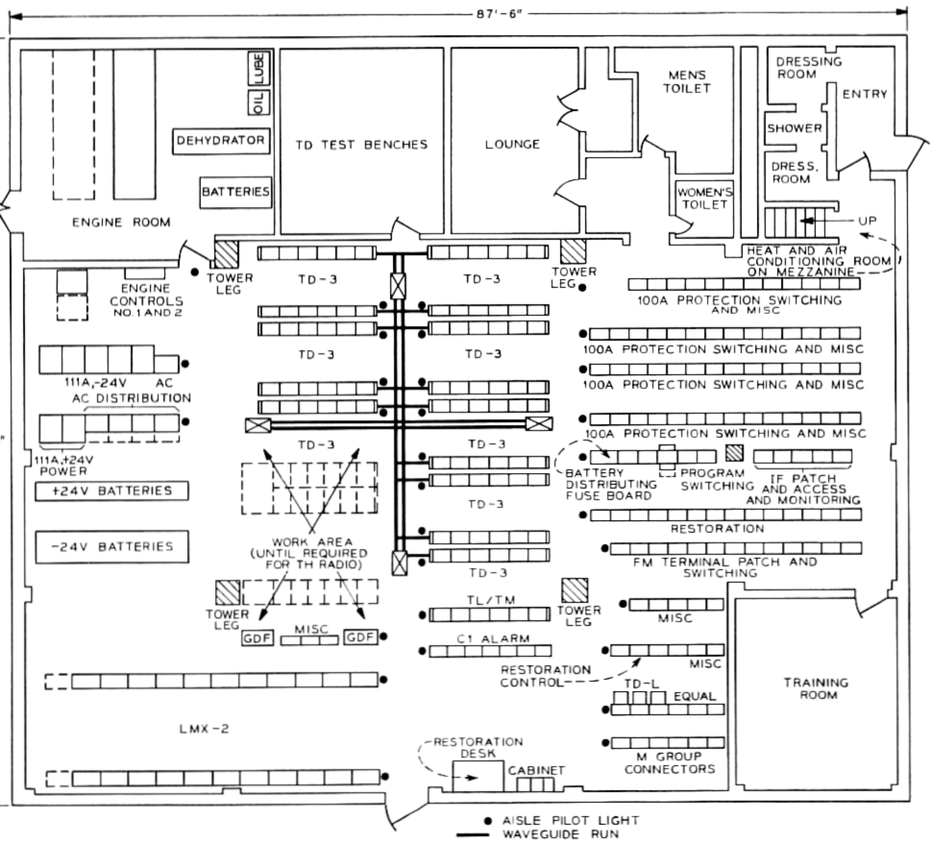


Fig. 5 — Main station floor plan at Arkabutla, Mississippi, on the initial TD-3 route.

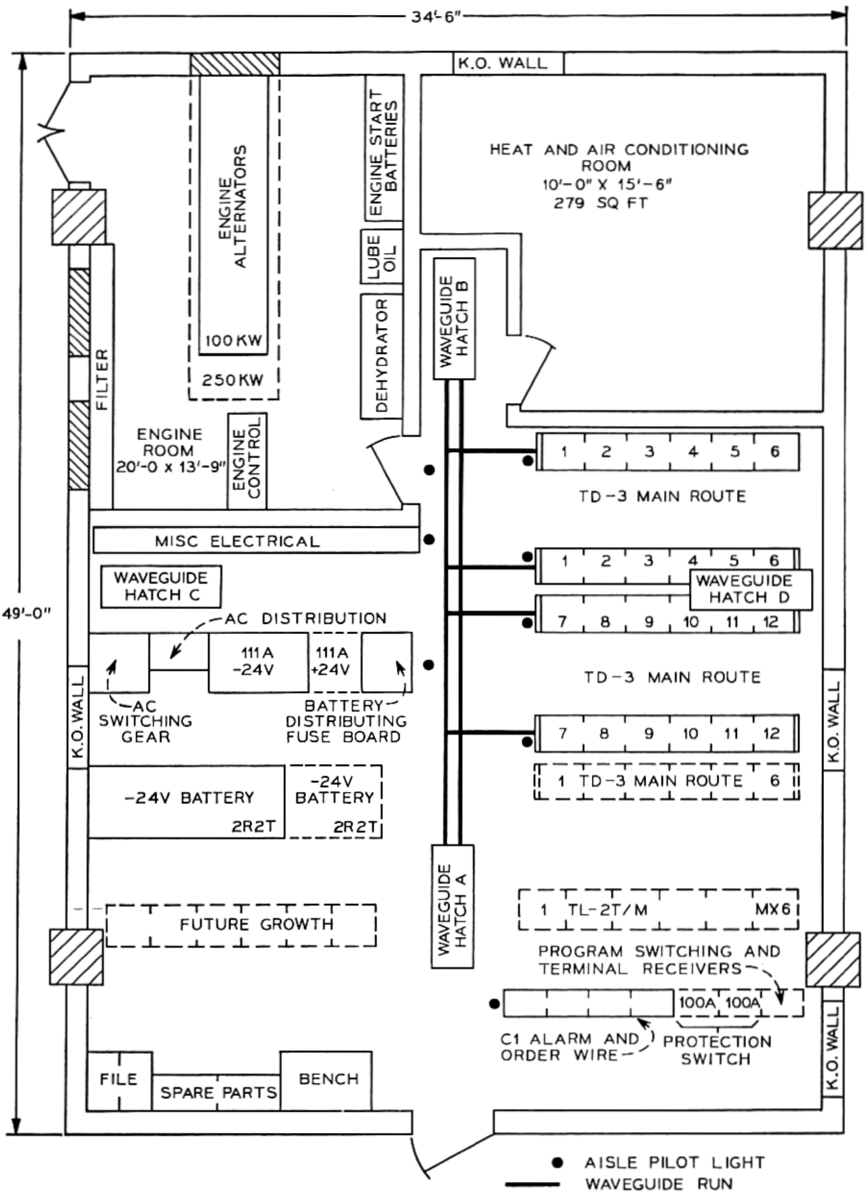


Fig. 6 — Floor plan of repeater stations on the initial TD-3 route.

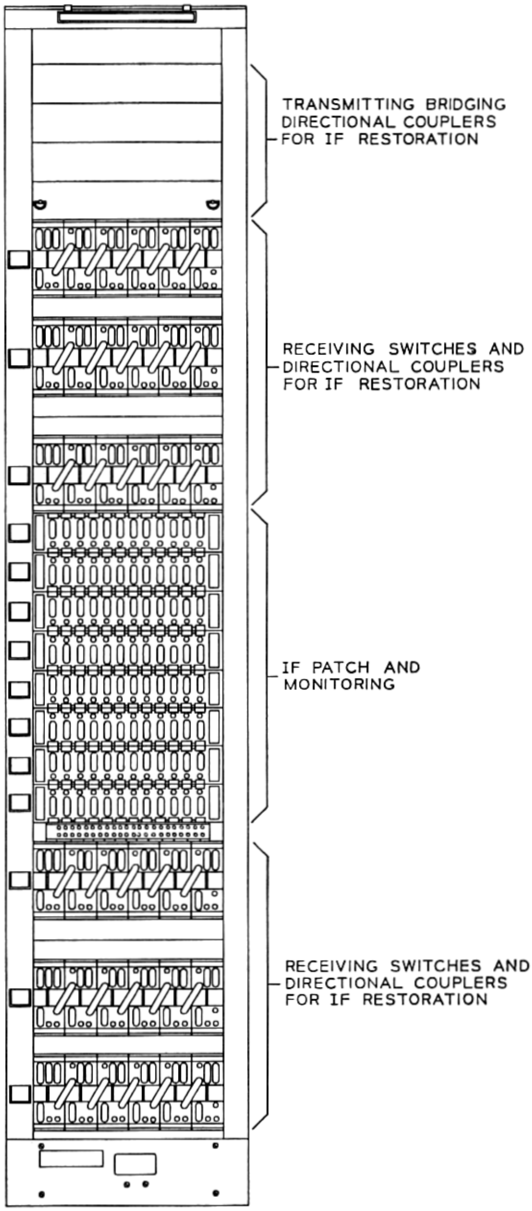


Fig. 7 — IF patch and access bay.

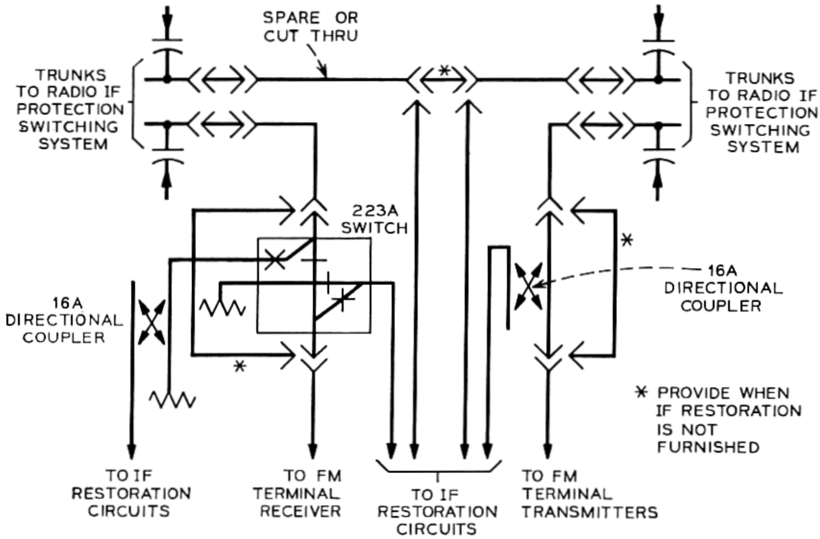


Fig. 8 — Typical application circuit for IF patch and access bay with monitoring taps.

in the equipment units where the alarms originate. The alarm system, which directs maintenance personnel by means of pilot lights on the aisles to the point of the alarm, is adapted for both main and repeater stations. Relays for common office alarm circuits such as open door and tower navigation lights, are mounted together at one location. These circuits also connect to the aisle pilot system. The existing C1 alarm and order system[3] or the new E1 system may be used as the connecting link to transmit alarm and status information from unattended stations to the attended control point and to transmit orders outward from the control point. The C1 alarm and order system is in wide use in the field. It uses relay type circuitry and has a maximum combined capacity of 882 alarm and station indications and 490 orders for each of as many as 12 stations per system. The new E1 system, using a combination of solid state and relay circuitry, has expandable capacity and will fulfill any foreseeable requirements for TD-3 radio with respect to transmission of information and the number of stations served. It has also been drastically reduced in size; that is, a maximum C1 system requires 7 frames of equipment whereas a comparable E1 system requires only a single frame.

New maintenance order circuits also are being introduced which include these basic improvements over the existing systems: (*i*) solid state circuitry is used, (*ii*) the order circuits are independent of the E1 transmission facility (*iii*) conventional dialing arrangements are available for signalling between stations, and (*iv*) the express and local order circuits may be interconnected when required.

## VII. DEHYDRATORS

A dehydrator is available for TD-3 offices to provide dry air at a positive pressure to the outdoor antenna waveguide system to prevent water accumulation thru condensation or leakage. Dry air is also used to charge the transmitter-receiver critical waveguide filter elements. These Invar filters require regulation of temperature and humidity to maintain frequency stability. By direct introduction of dry air into the filter cavities the station temperature may be allowed to vary within reasonable limits namely, 70 ± 20°F and no requirements need be placed on humidity. The dehydrator operates on a combined refrigerating and desiccant principle and will provide 100 cubic feet per hour of −40° dew point air at a pressure of approximately 7 inches of water. It is estimated that a leakage of about 0.8 cubic foot per hour per bay, or approximately 20 cubic feet per hour for a repeater station with 24 bays, will occur. Available information shows that an average antenna system may leak about 8 cubic feet per hour, or a station equipped with 4 antennas may leak at a rate of about 32 cubic feet per hour. However, corrective maintenance is not undertaken until antenna system leakage approaches 15 cubic feet per hour. This leakage rate, therefore, determines the ultimate air usage and results in a total approximate requirement of 80 cubic feet per hour for a repeater station. This amount can be furnished by a single dehydrator. At larger repeater stations and at main stations additional dehydrators are needed. The dry air for the antenna system is delivered to the waveguides at the pressure windows by a manifolding arrangement. This dry air to the channel dropping filters is introduced through the inside waveguide using a flange-type fitting located adjacent to the waveguide pressure window. When two separate dehydrators are furnished, separate manifolding runs are used. A manual transfer valve is provided so that in the event of failure of one dehydrator, the remaining unit can provide the total supply at some reduction in pressure.

## VIII. ANTENNA SYSTEM

The horn reflector antenna with circular waveguide and systems combining (or separation) networks, used in the earlier TD-2 and TH systems, is also used with TD-3. This antenna system, capable of simultaneously carrying orthogonally-polarized signals in the common carrier frequency bands of 3.7 to 4.2, 5.925 to 6.425 and 10.7 to 11.7 GHz, has been described in detail in previous papers.[4–6]

A vertical run of circular copper waveguide (2.81 inch inside diameter) connects the antenna to appropriate systems combining networks at the base of the antenna supporting structure. Since two polarizations, vertical and horizontal, are available for each of the three frequency bands, as many as six rectangular waveguides may connect from a single run of circular waveguide to the transmitter-receiver bays in the microwave radio equipment room. The antennas, networks, and all outdoor waveguides are pressurized with dry air. An RF window in the waveguide at the building entrance separates the outside and inside waveguide sections.

Generally, a repeater station is equipped with four antennas, one transmitting and one receiving in each direction, while stations located at route intersections may have six or more antenna systems. Therefore, plans for fully-equipped stations must provide for as many as six rectangular waveguides per antenna—at least 24 waveguides at a repeater station and more at main stations.

To avoid undue signal attenuation and to control noise contributions of the antenna system, the waveguide runs should be kept as short as possible and, therefore, must be carefully engineered and installed. Standardization or pre-engineering of waveguide runs is highly desirable but difficult to achieve with rigid waveguide. The arrangements for the tower-mounted circular waveguides and the indoor portions of the rectangular waveguides have been standardized. The outdoor rectangular waveguide runs are generally specially engineered for separate building and tower structures—each situated according to its own requirements with respect to radio path directions and local site conditions. Nevertheless, they usually follow typical patterns.

## IX. BUILDINGS AND TOWERS

The building and tower shown in Fig. 9 are typical of those being used for TD-3, TD-2, and TH. The building is a reinforced concrete structure with 1625 square feet of equipment floor space.

The tower will accommodate four horn reflector antennas and a pair of 8-foot-diameter parabolic antennas. At the station shown in Fig. 9, the shrouded antennas, mounted approximately 50 feet below

Fig. 9 — This installation at Dumas, Mississippi, is typical of current TD-3 repeater stations.

the horn-reflectors, are used in a narrow-band space diversity system, operating at 4190 or 4198 MHz, which provides a high-reliability auxiliary channel for order and alarm circuits.

The towers used at main stations have the capacity for mounting eight horn reflectors on two top platforms. Both "four and eight antenna" towers of this tapered truss design are available in heights up to 350 feet. Galvanized ASTM A 36 steel is used, although for economy some leg sections are made of high strength steel (ASTM A 441). Pier-and-pad footings, independent of the building foundations, are generally used so that the tower is 15 to 20 feet from the building. The separation is sometimes greater, although in recent construction it has been held to a minimum. For a four-antenna tower, the tower base width varies from about 18 to 53 feet, and is even larger for an eight antenna tower.

The systems combining networks are mounted on the outside face of the tower. Waveguide support trusses carry the rectangular waveguides from these networks to the entrance panels in the rear wall of the building. Both the networks and the horizontal waveguide runs are covered to prevent damage from falling objects or ice.

It is difficult to standardize outdoor waveguide arrangements with separate buildings and towers because of (*i*) the large number of variations in tower base dimensions and building-tower separations, (ii) the occasional positioning of the tower at an odd angle with respect to the building plan, and (*iii*) the need to connect antennas located in various positions on the tower with transmitter-receiver bays which are uniformly placed within the building. Furthermore, the building-tower separation and the relatively large dimensions of the tower base result in long rectangular waveguide runs. To eliminate many of the problems associated with outdoor waveguide arrangements, a new approach was used on the TD-3 system installed between Alexander, Arkansas, and Arkabutla, Mississippi. A "unitized" building-tower arrangement with relatively short pre-engineered waveguide runs was used. In this arrangement, the tower is mounted directly on a reinforced concrete building. The tower legs are anchored to the building columns and the tower footings are integral with the building foundation.

"Unitized" designs were developed for both repeater and main stations. The unattended repeater building provides approximately 1800 square feet of equipment floor space, including separate engine and mechanical equipment rooms. Figure 10 shows the "unitized" type at Stuttgart, Arkansas, where the tower is about 287 feet high. Anticipating future growth, this tower is designed to support as many as six horn-reflector antennas. The availability of eight possible antenna mounting positions on a large platform offers a wide range of orienta-

Fig. 10 — The repeater station at Stuttgart, Arkansas, on the initial TD-3 route, uses a "unitized" building-tower arrangement.

tion possibilities, so that it rarely will be necessary to orient the tower with respect to the microwave paths as must frequently be done with conventional towers for four antennas.

Corresponding main junction buildings, such as those provided at

Alexander, Arkansas, and Arkabutla, Mississippi, are several times as large as those used for the repeaters. They provide additional space for the protection switching, terminal, order wire and alarm, patching, and test equipment, as covered in Table I, as well as multiplex or other locally required equipment. The building at Alexander, with a 137 foot tower (Fig. 11), is designed to support 12 horn-reflector antennas—four on a second platform. A second floor on one side of the building (right in Fig. 11) houses air conditioning and heating equipment.

The towers in the "unitized" construction are galvanized steel 33 feet on a side, up to 350 feet high. The legs are wide flange H sections of high strength steel (ASTM A 441), ranging from six inches deep and weighing 15.5 pounds per foot near the top, to 14 inches deep and weighing 150 pounds per foot at the base of the heaviest tower. Each baseplate is secured by anchor bolts to the building column on which it rests. For the heaviest tower, eight 3-inch diameter bolts are required at each leg. The towers are designed to withstand loads corresponding to approximately 100 mph winds. In a 70 mph wind, the antenna platforms will deflect less than ¼ degree.

The large and uniform tower cross-section permits the running of the circular waveguide straight and inside the tower, rather than in the sweeping arc (500-foot radius) which brings it tangent to the outside face of the usual tapered tower. Short rectangular waveguide runs connect from the systems combining networks, mounted inside the tower face at roof level, to one of four entrance hatches on the roof. Networks and rectangular waveguide are protected from falling objects or ice by steel grating supported at the top of the tower base section which may be at a level 18 or 31 feet above the roof. In a departure from usual practice, the rectangular waveguide is positioned with its long dimension vertical so that small amounts of water or other foreign matter which may enter the guide can collect on the narrow side, where it has less effect on transmission.

Both the conventional and "unitized" buildings have exterior wall panels designed to facilitate their removal in the event the building must be enlarged. They also provide facilities for 100 kW engine alternators with room to expand the emergency power service to 225 kW if necessary.

Air conditioning in the trial installation was designed to maintain the radio equipment space at 75 ± 10°F, with relative humidity below 50 percent. As the Invar waveguide filter elements are now being pres-

Fig. 11 — The main station at Alexander, Arkansas, on the initial TD-3 route.

surized with dry air, the station temperature requirement for future construction is 70 ± 20°F with no limits on relative humidity.

In accordance with Bell System plans for continuity of communications in the event of nuclear attack, all structures are designed to withstand 2 psi peak overpressure and associated blast effects. Attended main stations are equipped with decontamination and emergency living facilities. Adequate shielding is provided to protect working personnel from fallout radiation.

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