

**ENGINEERING AND IMPLEMENTATION METHODS SYSTEMS (EIMS)
DIGITAL HIERARCHY
DIGITAL TRANSMISSION SYSTEMS**

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1. GENERAL

1.01 This document presents an Engineering and Implementation Methods System (EIMS) for Digital Transmission System applications. An overview of the overall process required to engineer and implement a Digital Transmission System is presented, which provides an overall appreciation of the process and avoids details of specific tasks. Documents (such as Bell System Practices and AT&T letters, etc) covering detailed instructions for the digital hierarchy have been indexed in the following Bell System Practices:

- DS1 (T1)—Section 365-010-001
- DS1C (T1C)—Section 365-010-002
- DS2 (T2)—Section 365-010-003
- DS3 (T3)—Section 365-010-004
- DS4 (T4)—Section 365-010-005.

Drawings for all of the above sections have been indexed in Section 365-010-006. A digital multiplex is indexed according to its highest digital signal (DS) rate. Hence, an M13 digital multiplex is indexed in Section 365-010-004.

NOTICE

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1.02 This section is reissued to include the DS1C, DS2, DS3, and DS4 digital signal rates. This issue includes information previously covered by Section 365-010-102—T4 EIMS for Digital System Applications. The activities covered in this section apply to all DS rates. The details of how to perform a specific activity on a specific DS level can be found in documents listed in the index for that DS rate. The indexes are discussed in paragraphs 1.01 and 2.06. Figures 1 through 6 have been added to provide a system application overview of each DS rate and how each rate fits in the digital hierarchy. Terms coined in issue one have been replaced with terms which are more specific or more commonly used. Since this reissue is a general revision, change arrows are not used. Equipment Test Lists are not affected by this issue.

2. DIGITAL HIERARCHY

DESCRIPTION

2.01 A T1 digital system begins at a D-type channel bank or similar terminal equipment, such as digital interface, No. 5 Electronic Switching System terminal, etc, at one location and ends with a compatible terminal at another location. Each D-type channel bank multiplexes up to 24 voice-frequency or data signals into one digital signal bit stream which is transmitted over a facility to the other terminal. Each channel bank also demultiplexes a bit stream received over the facility back into voice frequency or data. A T1 bit stream is 1.544 Mb/s (megabits per second), which is the DS1 digital signal rate.

2.02 The evolution of digital transmission beyond T1 has resulted in a number of digital transmission systems (T1C, T2, T3, and T4) of higher capacity being designed to operate at higher bit rates. At present, a 5-level hierarchy has been established, DS1, DS1C, DS2, DS3, and DS4. (See Fig. 1.) Each level of the hierarchy has a fixed bit rate and a maximum number of voice circuits which can be carried by a transmission facility operating at the particular level.

2.03 Digital systems which have signal rates higher than the T1 rate usually consist of two multiplexes and a connecting facility. (The D4 channel bank may be configured to have a DS1, DS1C, or a DS2 digital output rate.) Each multiplex receives signals from lower DS rate systems and multiplexes them into one bit stream

which is transmitted over the facility to the other multiplex. Therefore, a digital system beyond DS1 acts as a facility for the systems feeding its multiplex. Each multiplex receives one bit stream from the distant multiplex over the facility and demultiplexes the bit stream back into the original signals.

2.04 It is strongly recommended that all digital systems have a DSX (digital cross-connect) panel between each multiplex and its facility to provide for patching, rerouting, and maintenance access. In the FT3 Lightwave Digital Transmission System, patching, rerouting, and maintenance access are available at the lightwave termination equipment.

2.05 Figures 2 through 6 show the five digital signal rates along with the optional connections to higher DS rates.

DOCUMENT INDEXES

2.06 Document indexes (Sections 365-010-001 through 365-010-006) have been designed to provide reference material to complement this EIMS. For this reason a short description of those sections is included here. Sections 365-010-001 through 365-010-005 have the same format but differ by the DS rate covered. A general introduction is given in Part 1. Part 2 contains a bibliography of official documents, such as Bell System Practices and system letters in alphanumerical order. Part 3 is a permuted title index which lists alphanumerically selected key words in the documents titles. Part 4 is the activity and equipment index which provides a list of reference documents for general activities such as plan, install, and maintain. It also provides reference documents for equipment categories such as terminals, DSXs, and outside plant. Part 5 is a permuted subject index which uses key words of subjects covered in the document but not included in the title. Part 6 lists references to paragraphs in this section.

3. PLANNING PHASE

TRAFFIC FORECASTS

3.01 Traffic forecasts, based on usage of the existing network and a knowledge of growth patterns in the communities served, form the basis for a trunk forecast document used as input to planning groups. This trunk forecast should be reissued at least annually through the coordinated

efforts of both traffic and network planning groups and should cover current and future circuit requirements for about a 5-year period.

3.02 Accurate special service forecasts are generally more difficult to provide than trunk forecasts. They should be provided as a separate document by the group or groups most knowledgeable in special customer demands.

3.03 The forecasts should be summarized in terms of point-to-point requirements for each pair of central offices in the network together with the dates when the requirements must be met. Section 790-100-210 can be used to forecast network growth.

CHOOSING THE RIGHT SYSTEM

3.04 Once the point-to-point circuit requirements have been determined, the next step is to meet those requirements as economically as possible while allowing for growth, including growth from one DS lead to another. Decisions for certain situations may be obvious. For example, slow growth in a certain suburb may call for a T1 facility while the higher capacity T4 facility may be the obvious choice in a metropolitan area. However, computing the cost per circuit mile for the many situations in between can be very complicated.

MATFAP

3.05 MATFAP (Metropolitan Area Transmission Facility Analysis Program) is a facility planning computer program intended to aid operating companies in planning T Carrier applications in metropolitan areas. The program has been designed to perform the following functions:

- (1) Provide mechanized facility selection and routing of point-to-point requirements
- (2) Identify projected facility exhaust dates
- (3) Provide the information necessary to analyze facility cross-section situations including existing and projected requirements
- (4) Provide rapid evaluation of various facility relief alternatives
- (5) Produce construction program, facility and equipment requirements, and broad-gauge

costs after the relief and deferral strategies have been selected.

A general description of MATFAP is given in Section 781-505-100.

ROUTING

3.06 The shortest route may or may not be the most cost effective route. There may, for example, be a high-rate digital facility between points A and B and a need for a lower rate digital facility between points A and C. It may be more economical in this situation to route the system over the high-capacity digital rate facility than to go from A to C directly. This method of routing is called "backhauling." Other factors to consider when planning a route are: (1) joint use of cable with other carriers, (2) use of existing unused cable pairs, and (3) the number of maintenance trunks needed.

4. ENGINEERING PHASE

4.01 Once the route and choice of facility have been determined, the engineering phase begins. The engineering phase has two parts—outside plant and central office (CO).

OUTSIDE PLANT ENGINEERING

Span Concept

4.02 A digital route consists of one or more tandem maintenance spans. Each span consists of ducted, buried, or aerial cable, or digital radio link between maintenance offices with repeater stations or radio relay stations located at specified intervals along the line. There are manholes or above ground stations along the line for splicing as well as for repeaters. Splices and repeaters are usually not located in the same structure. The designing of a digital route can be reduced to designing the individual spans. The locations of maintenance offices are normally in COs and determined during the planning phase.

Route Survey

4.03 An integral part of the engineering of a maintenance span is a field inspection (route survey) of the proposed route to be followed (the proposed route to be followed should have already been determined during the planning process).

Certain aspects of the route must be determined before any detailed design can be started. If existing cable is not being used, the engineering of a span involves cable placements as part of the design (the particular cable size to be used should have already been determined in the planning process). Therefore, the locations, distances, cable run, conduit construction, and any unusual conditions for placing the cable are determined in this route survey. In addition, preliminary splicing manhole and repeater site locations are also located based on the required regenerator spacings. The maximum distance between line regenerators depends on the facility and the specific cable type being used. However, if growth patterns indicate that a T1 digital line may be converted to a T1C or a T1D digital line, care should be taken to make distances between repeaters compatible with both systems. Therefore, placement of repeater stations must be restricted to a distance below this maximum. If existing manholes are being used, they may require enlargement in order to accommodate the apparatus and maintenance cases. In some situations, off-line auxiliary manholes or stations may be required. Regenerator stations for the FT3 system must have a central office environment. Therefore, construction of environmentally controlled vaults above or below ground may be necessary. After the various regenerator section lengths are determined, the repeater locations are chosen.

4.04 Once the above task is accomplished, the information obtained is used to determine formally the route to be followed and to prepare a route layout sheet.

Obtain Legal Right-Of-Way

4.05 Investigation in such matters as the securing of right-of-way, the general ownership of property, etc, usually follows the preliminary route survey (if existing ducted routes are being used, then, right-of-way is not usually required). It is not advisable to undertake detailed route design work before all necessary permits have been secured, since drastic changes in the route could occur as a result of conditions unveiled by the investigation.

Powering

4.06 Factors for powering digital lines include temperature fluctuations, length of span, type of repeaters, and the number of repeaters in

a span. Powering for short spans may be done from one end while longer spans require offices at both ends of the span to provide power. The T2 digital line has intermediate power stations. The FT3 digital line requires local power for each regenerator.

Determine Outside Plant Equipment

4.07 The type of facility, the initial capacity of the line, and the number of repeater stations determine the number and type of outside plant plug-ins. Western Electric Company, Inc. (WE), offers installation and maintenance for the FT3 lightguide cable. FT3 lightguide cable requires positive flow pressurization.

CENTRAL OFFICE ENGINEERING

4.08 This section enumerates the major tasks involved in engineering a central office (CO) for the installation of digital system equipment. The maintenance office which contains equipment to monitor, maintain, administer, and power (when necessary) a digital line is located in a CO. In addition, the CO contains the multiplex equipment, when required.

Central Office Considerations

4.09 The buildings built or selected to serve as maintenance offices or lightwave line repeater stations should be inspected and an overall office plan developed before the office equipment is installed. The office plan should be planned for the ultimate size of the office and include the following:

- (1) Equipment required for initial service needs—specific configuration
- (2) Floor plan layouts (bay arrangements, procedure for growth)
- (3) Power requirements and distribution
- (4) Cable racking layouts—cabling philosophy
- (5) Air conditioning and lighting
- (6) Earthquake and fire protection.

Western Electric Company, Inc., assistance is usually helpful in generating this plan since they normally

install the CO equipment. Some of the items to be included in the plan are discussed in the following paragraphs.

4.10 Equipment required for initial service includes line terminating equipment, DSX cross-connects, D-type channel banks, and multiplexes if needed; in short, the items shown in Fig. 2 through 6 that apply to the configuration selected. The capacity planned for, divided by the capacity of each piece of equipment, roughly determines the number of pieces needed.

4.11 Battery-backed dc office power is needed for D-type channel banks, multiplexes, DSX cross-connects, line termination equipment, and digital line facilities. Power must be within the operating limits of the equipment being used.

Floor Plan and Cable Runs

4.12 A well thought-out floor plan which allows for growth should be developed. It should be based on the ultimate size of the office. It should consider the maximum distances allowed for various connections and the relative location of equipment to facilitate maintenance. Floor Plan Data is the primary source of information used in the development of floor plans for central office equipment systems. In addition, Sections 760-100-084 (and 085) provide extensive planning guidelines for digital carrier terminal offices. These guidelines cover equipment layout, cabling, lighting, cooling, and total office plans.

Office Maintenance Plan

4.13 In conjunction with the office plan outlined above, an overall maintenance plan should be developed for the system. This maintenance plan should include the following:

- (1) Alarm and maintenance philosophy
- (2) Alarm display and remoting
- (3) Procedures for restoration
- (4) Equipment configuration to implement maintenance plan (including assignment of protection lines)
- (5) Order-wire arrangements

(6) Cable pressure monitoring.

Telephone Office Planning and Engineering System (TOPES)

4.14 The Telephone Office Planning and Engineering System (TOPES) is intended to aid operating companies in the preparation of study and engineering plans for central offices. TOPES planning aids provide broad-gauge estimates of equipment, floor space, and electrical and mechanical support system requirements. The system enables rapid preparation of study plans and facilitates consideration of alternative plans. Conferencing features improve communications between various groups involved in study plan preparation and approval.

5. IMPLEMENTATION PHASE

5.01 The implementation phase outlines the major system installation tasks required to transform a route design into a working system and/or facility. Emphasis should be made, at this point, to the various interdepartmental coordinations required so that all interrelated phases of the work can be completed in sufficient time to meet the first service date for the system. The specific job responsibilities of the various departments are described in paragraphs 5.02 through 5.13. The various tasks are divided into three major areas of responsibility: outside plant, central office, and maintenance and administration. This explanation is not intended as a complete description of the specific detailed work operation of any department. Rather, enough of each department's responsibilities is presented to give an appreciation of interdependence during the implementation phase. The specific work operations described may vary depending on the operating company implementing the system.

ESTIMATE PREPARATION AND APPROVAL

5.02 Specific estimate authorization (Section 935-111-430) for both outside plant and office equipment expenditures should be prepared and approval obtained. (Construction budget provision for any required construction should have already been made). Federal Communications Commission (FCC) approval (if required) should be secured prior to the approval of the specific outside plant estimate. Once the authorization has been approved, all other phases of implementation may be started.

INTERDEPARTMENT MEETING

5.03 With approval of the specific Estimate Authorization, it is suggested that a meeting with the representatives of at least the following departments be held:

- (1) Plant
- (2) Equipment Engineering
- (3) Transmission Engineering
- (4) Plant Extension Engineering
- (5) Traffic
- (6) Building Engineering
- (7) Maintenance and administration.

5.04 Operating companies with no prior experience with the installation of the digital system selected should initiate this meeting during the engineering phase. The purpose of this meeting is to alert the various departments of the impending introduction of the system. The final detailed route design should be reviewed, and the concurrence of all departments for the work operation sequence should be obtained. Specific responsibilities for each work operation should be fixed and a time schedule determined.

5.05 An example schedule that illustrates the chronological relationship of important events and milestones in an FT3 Lightwave System installation is shown in Fig. 7. The assumptions in determining this example schedule are noted in the figure. It should be noted that this schedule is an example; schedules for other systems will vary from that shown.

5.06 Subsequent progress meetings of this interdepartmental committee should be held on a scheduled basis during the implementation phase.

TRAINING

5.07 The requirements for training with each department must be critically analyzed based on the complexity of the system being installed. Training is perhaps most critical in the construction, installation, repair, and CO divisions of the plant

department. Definite times for training should be scheduled as carefully as the installation of equipment. Training should also include craft management in departments whose work activity may affect system operation.

OUTSIDE PLANT TASK LIST

5.08 This section identifies the tasks for procurement, installation, and test of the outside plant (OP) facilities. The preparation of the digital line OP, in general, will be the responsibility of the operating company OP department. However, Western Electric Company, Inc., offers EF & I (engineer, furnish, and install) and maintenance on FT3 lightguide and lightwave line repeater stations. Right-of-way, easement, purchase of site property, and FCC approval (if required) should have already been secured. In addition, for routes where new cable is to be installed, the appropriate cable should be ordered following the required delivery interval.

Repeater Station Construction and Cabling

5.09 The nature and extent of conduit and repeater station construction or modification will vary from route to route depending on the particular operating company location. The digital route requires repeater stations at appropriate spacings. Depending on the system used and the route chosen, repeater stations may be in manholes, central offices, environmentally controlled vaults, pole-mounted apparatus cases, or above-ground repeater huts.

5.10 The following tasks are performed concerning repeater stations and cabling on an as-required basis:

- (1) Repeater station placed or constructed
- (2) Cable is placed and spliced
- (3) Equipment and cable racks are installed in repeater stations
- (4) Pressurizing equipment is attached to cable
- (5) Cable is tested
- (6) Plug-in units are installed at repeater stations.

CENTRAL OFFICE TASK LIST

5.11 This part identifies the tasks for planning the installation of equipment in a CO.

Central Office Equipment Order

5.12 From the detailed route design, a consolidated list of equipment by type is prepared and the appropriate equipment orders forwarded to WE. This should include test sets. Ordering information for the digital systems can be found in Common Language Sections (795-209-XXX). The plug-in type equipment orders should be closely coordinated with the particular agency responsible for the administration of this equipment, such as PICS (Plug-in Inventory Control System) or its equivalent, and should be on the same order as the CO equipment. Plug-in units include line regenerators and all manhole circuit packs as well as units to equip CO equipment bays. In addition to the circuit packs required for the initial system capacity, the order should include the sparing percentage required (approximately 10 percent is recommended, but the exact number of spares can usually be found in the J-code specifications). Therefore, initial plug-in stock and sparing ratio, as well as appropriate administrative procedures, should be established. This normally requires a joint effort involving outside plant and equipment engineering, the PICS administrator, and plant assignment.

Central Office Equipment Installation

5.13 Based upon the telephone company order and floor plan layout, a detailed specification is prepared usually by WE which indicates what equipment is to be installed, where the equipment bays will be located within the office, and where equipment is to terminate. In most cases, the installation of office equipment is performed by WE installers. This installation is carried out in two stages. The first stage, usually performed by WE, consists of installing cable rack and the various equipment bays, powering, and interbay cabling. A second stage of installation, usually performed by operating telephone company personnel, involves the physical arrangement of circuit packs, within equipment shelves. Turn up of office equipment should be coordinated with outside plant. The initial circuit packs may be installed by WE, whereas future additions are installed by operating company personnel. The equipment engineer determines

how many plug-ins should be installed to meet immediate system requirements and the anticipated growth in the near future. Subsequent installations of plug-in units are made in specific increments.

Acceptance Tests

5.14 Once the line and office equipment is installed, acceptance test procedures are carried out by operating company craft. The details of how the various tests and acceptance procedures are conducted are described in Task Oriented Practices (TOP) sections and/or conventional Bell System Practices sections.

OVERALL SYSTEM TESTING AND CIRCUIT ORDER WORK

5.15 After each major system component becomes functional in each office (acceptance test complete) they must be interconnected and verified operational end to end. This usually proceeds by building from the highest digital rate down to the DS1 rate in the following steps, eliminating steps involving DS rates not included in the route design:

DS4 Rate	A —Test from span terminating frame (STF) to STF over T4M digital line and B —Test from M34 multiplex to M34 over A
DS3 Rate	C —Test from M13 multiplex to M13 over B or DS3 digital radio or D —Test from MX3 multiplex to MX3 over B or over FT3 lightwave facility or DS3 digital radio
DS2 Rate	E *—Test from M12 multiplex to M12 over D or T2 digital line
DS1C Rate	F *—Test from M1C multiplex to M1C over D , T1C digital line, or T1D digital line
DS1 Rate	G *—Test from D-type channel bank over C , D , E , F , T1 digital line, or 1ARDS

* The D4 channel bank accepts 48 voice circuits and can feed directly to two DS1 facilities or one DS1C facility, or two D4 channel banks can feed a combined signal into one DS2 facility.

SECTION 365-010-101

5.16 Each step is verified for error-free operation before proceeding to the next step. After step-by-step verification of correct operation of the facility and supporting equipment such as fault lines, the system can be considered ready for assignment of traffic. Circuits (or systems) can then be patched in for service at the appropriate cross-connect points according to circuit order requirements.

6. MAINTENANCE PHASE

6.01 The maintenance of a system includes the monitoring of office equipment alarm indicators (audible and visual) and the analysis of alarm patterns in order to sectionalize a failure to a major component of the system. The following paragraphs describe some of the most important maintenance features. Details on how specific maintenance procedures are performed can be found in referenced sections.

ALARM FEATURES

6.02 System components are arranged to activate office audible and visual alarms. They may also be arranged for remote control, remote reporting of alarms, and status indications via T Carrier Administration System (TCAS) to a central location for a T Carrier Restoration Control Center (TRCC). TCAS uses E2 telemetry.

6.03 There are two classes of alarms, nonservice affecting (minor) or service affecting (major) alarms. Service affecting alarms are generally those which indicate a failure has occurred which is adversely affecting service. Nonservice affecting alarms are generally those which indicate a need for maintenance attention, but service quality is not affected.

TROUBLE SECTIONALIZATION

6.04 Trouble sectionalization for digital systems is performed by analyzing the major alarm patterns from the equipment. Alarm patterns are covered in the trouble clearing sections for each piece of equipment.

RESTORATION OF SERVICE

6.05 Some systems, especially at higher DS rates, have automatic protection switching which causes the system to switch to a working standby without loss of service whenever there is a failure. Systems without this feature must be patched manually. Patching and restoration procedures are described in maintenance sections.

RETURN/REPAIR PROCEDURE

6.06 Return procedures may vary with location. A description of PICS (Plug-in Inventory Control System) is found in Section 756-140-120. Forms used in dealing with PICS are described in Sections 756-14X-XXX.

7. REFERENCES

7.01 The following sections give additional information:

SECTION	TITLE
365-010-001	DS1 Systems—Document Indexes—Digital Transmission Systems
365-010-002	DS1C Systems—Document Indexes—Digital Transmission Systems
365-010-003	DS2 Systems—Document Indexes—Digital Transmission Systems
365-010-004	DS3 Systems—Document Indexes—Digital Transmission Systems
365-010-005	DS4 Systems—Document Indexes—Digital Transmission Systems
365-010-006	DS1 Through DS4 Drawing Indexes—Digital Transmission Systems
756-140-120	PICS/1 Users Guide—Business Information Systems—Trunks and Special Services
760-100-0XX	Space Planning—Building Engineering
781-505-100	Metropolitan Area Transmission Facility Analysis Program

SECTION	TITLE	SECTION	TITLE
	(MATFAP)—General Description— Interoffice Facility Planning— Technical Planning	795-209-XXX	Digital Carrier Systems—Encoders— Common Language
790-100-210	Forecasting Network Growth and Measuring Network Usage—Central Office Equipment Engineering— Administrative Practices	935-111-430	Preparation of Specific Estimate Authorizations — Administrative Procedures and Methods — Outside Plant Engineering — Management Organizing.

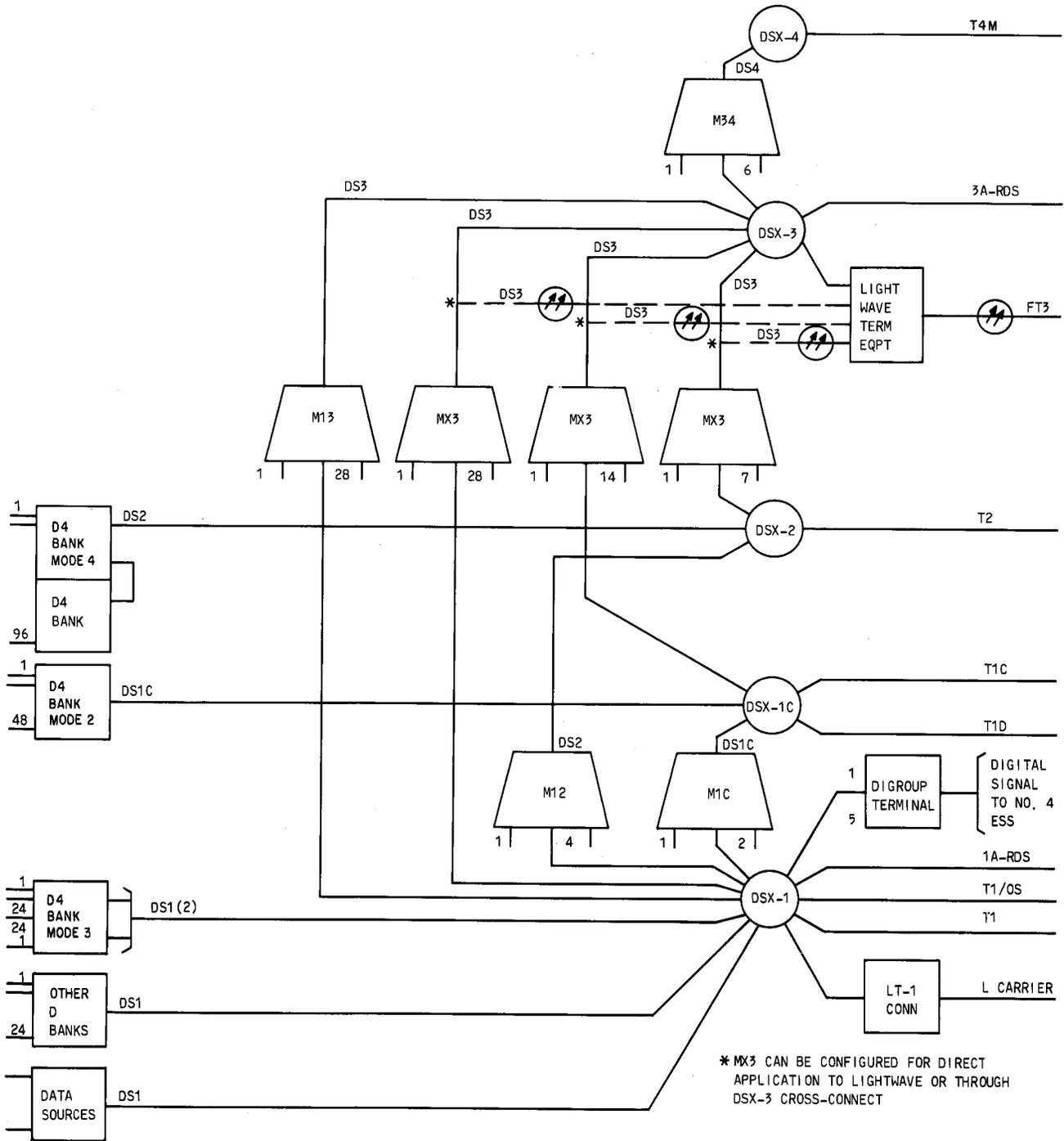
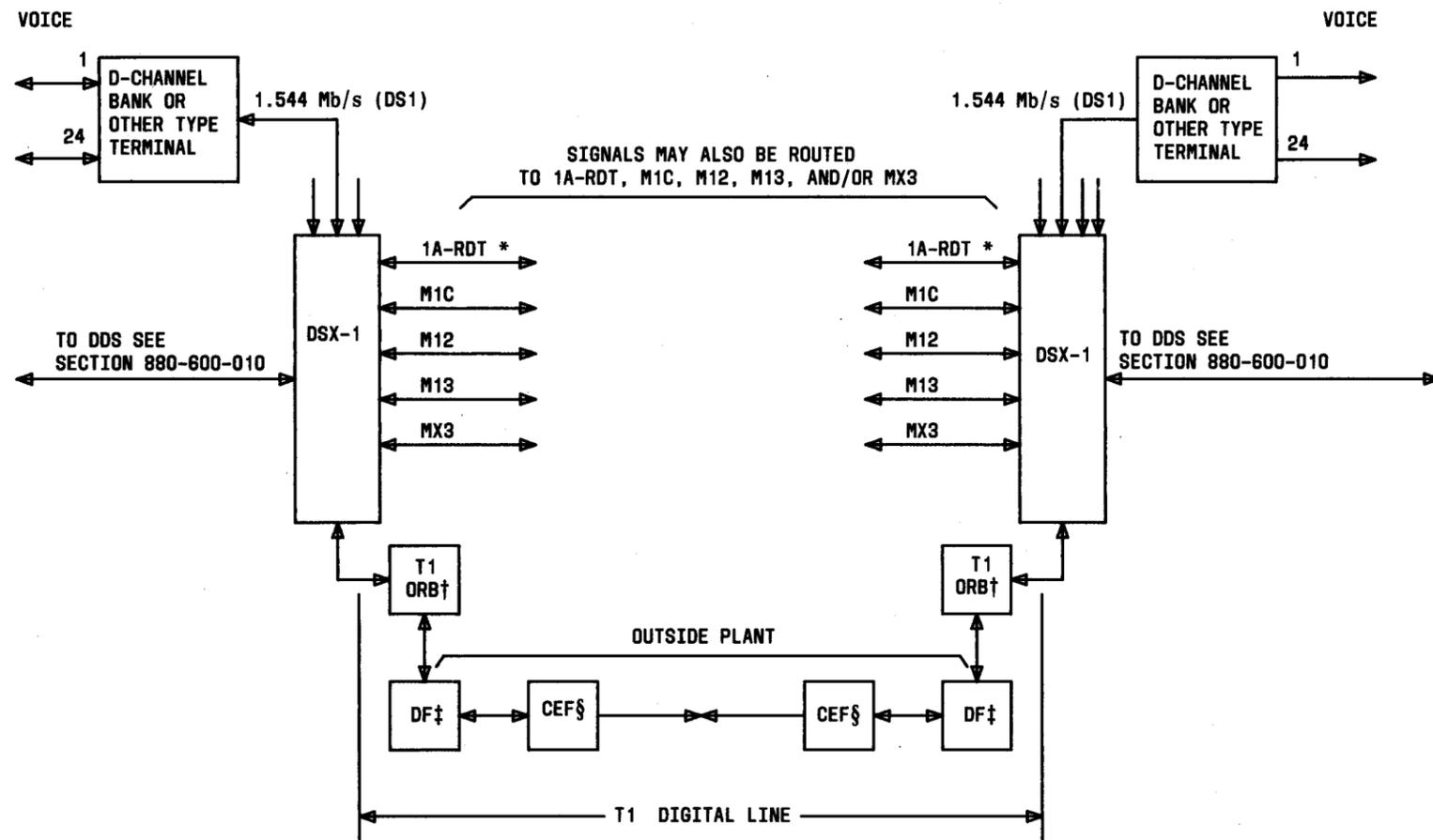
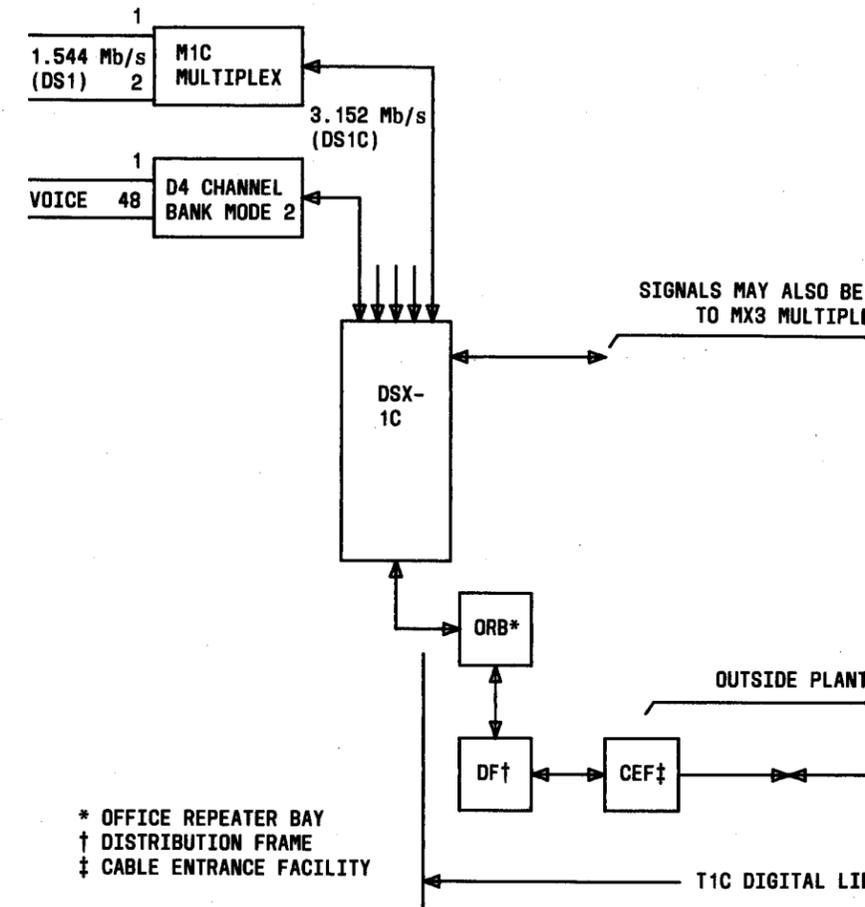


Fig. 1—Digital Hierarchy and Transmission Facilities



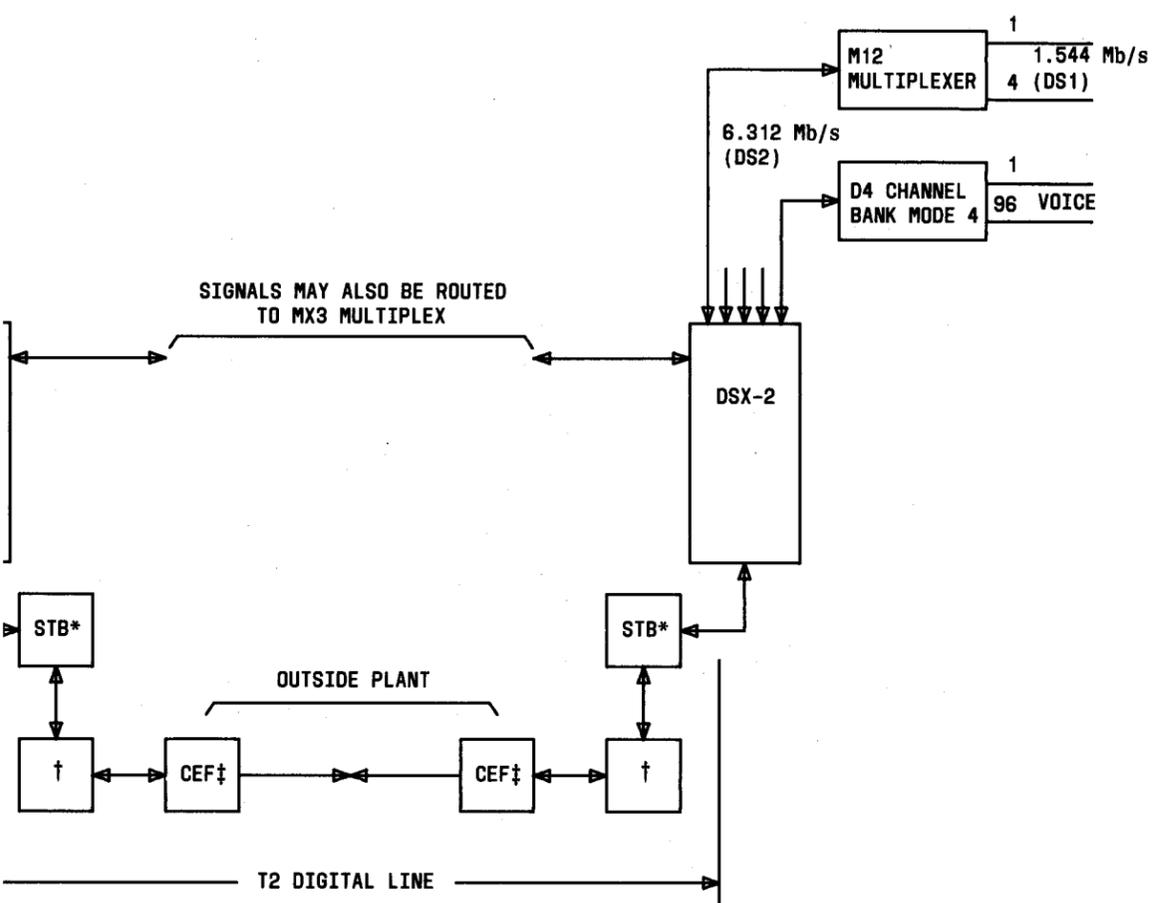
* SEE SECTION 855-322-101
 † OFFICE REPEATER BAY
 ‡ DISTRIBUTING FRAME
 § CABLE ENTRANCE FACILITY

Fig. 2—T1 Digital System (1.544 Megabits per Second)

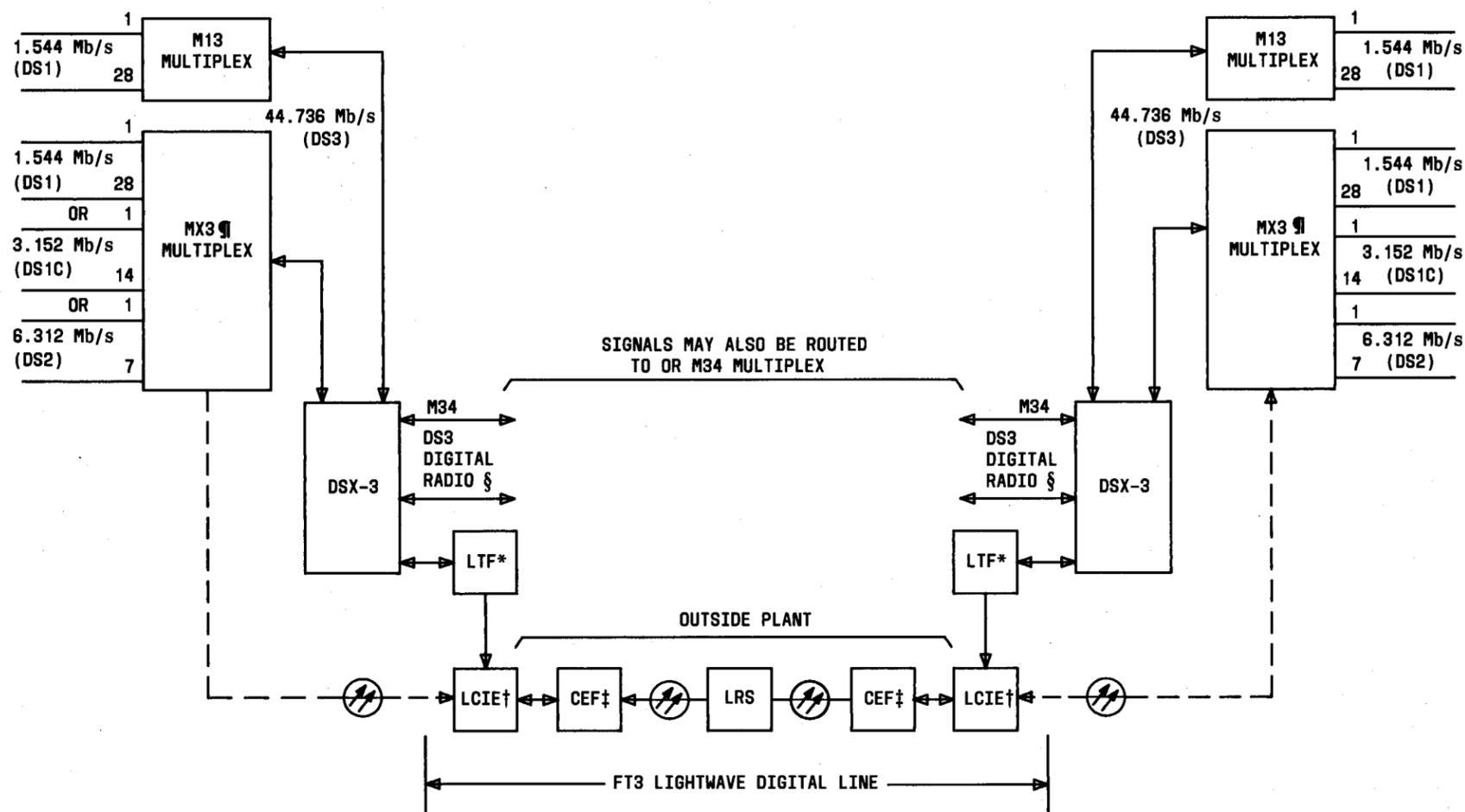


* OFFICE REPEATER BAY
 † DISTRIBUTION FRAME
 ‡ CABLE ENTRANCE FACILITY

Fig. 3—T1C Digital System (3.152)

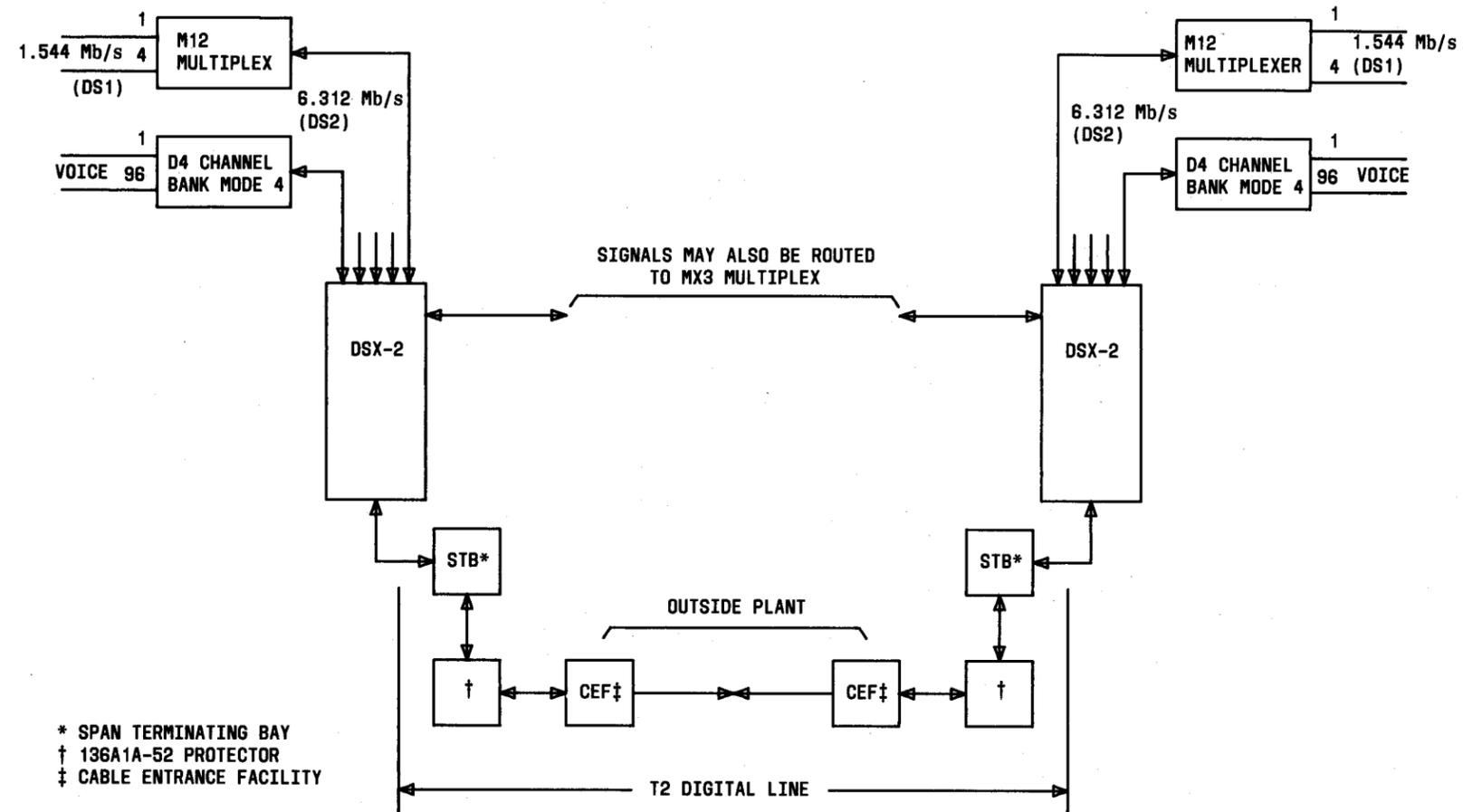


-T2 Digital System (6.312 Megabits per Second)



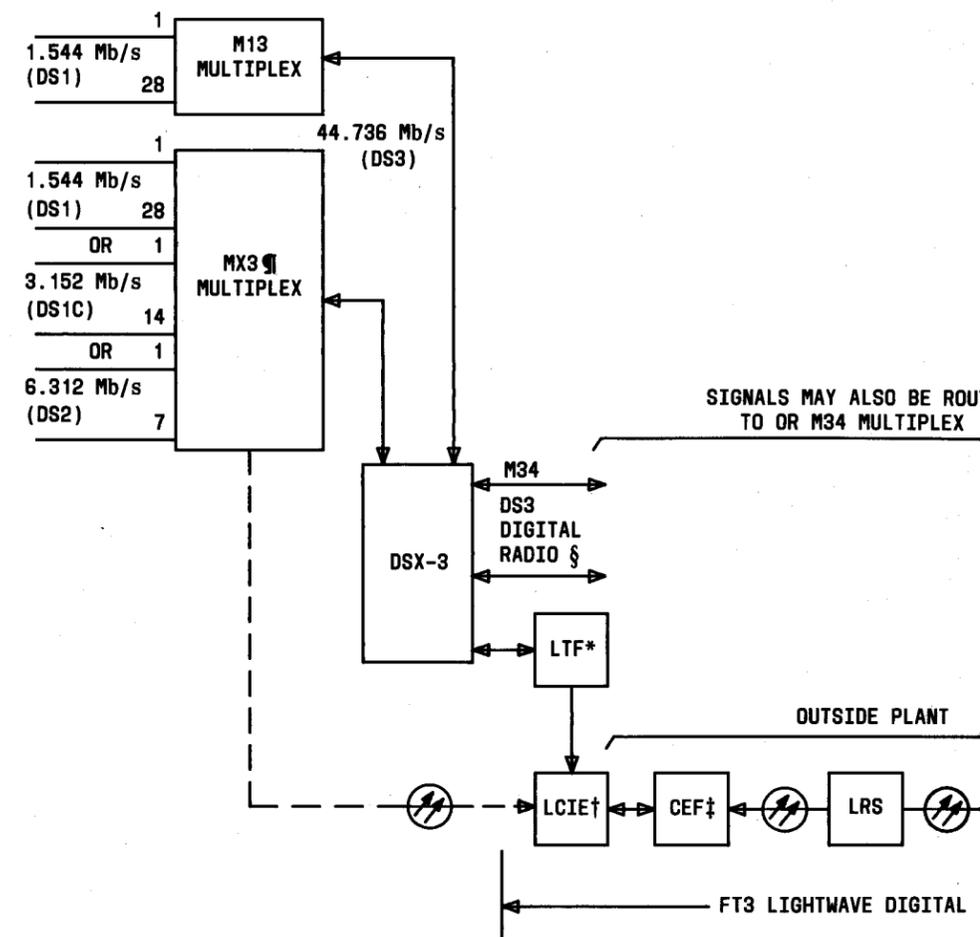
* THE MX3 MAY BE PART OF THE LTF
 † LIGHTGUIDE CABLE INTERCONNECTION EQUIPMENT
 ‡ CABLE ENTRANCE FACILITY
 § SEE SECTION 417-000-000
 ¶ THE MX3 MAY BE EQUIPPED FOR A LIGHTWAVE OR COAX OUTPUT BUT NOT BOTH AT THE SAME TIME

Fig. 5—T3 Digital System (44.736 Megabits per Second)



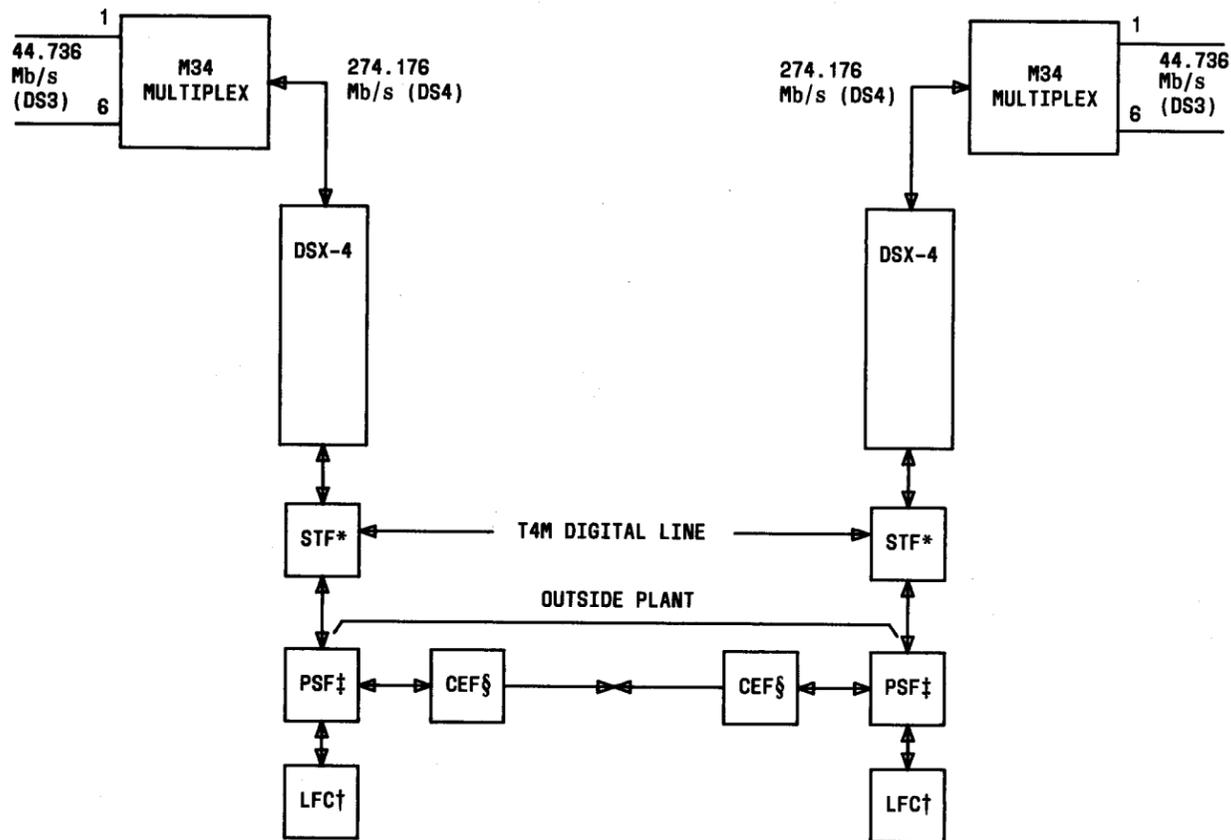
* SPAN TERMINATING BAY
 † 136A1A-52 PROTECTOR
 ‡ CABLE ENTRANCE FACILITY

Fig. 4—T2 Digital System (6.312 Megabits per Second)



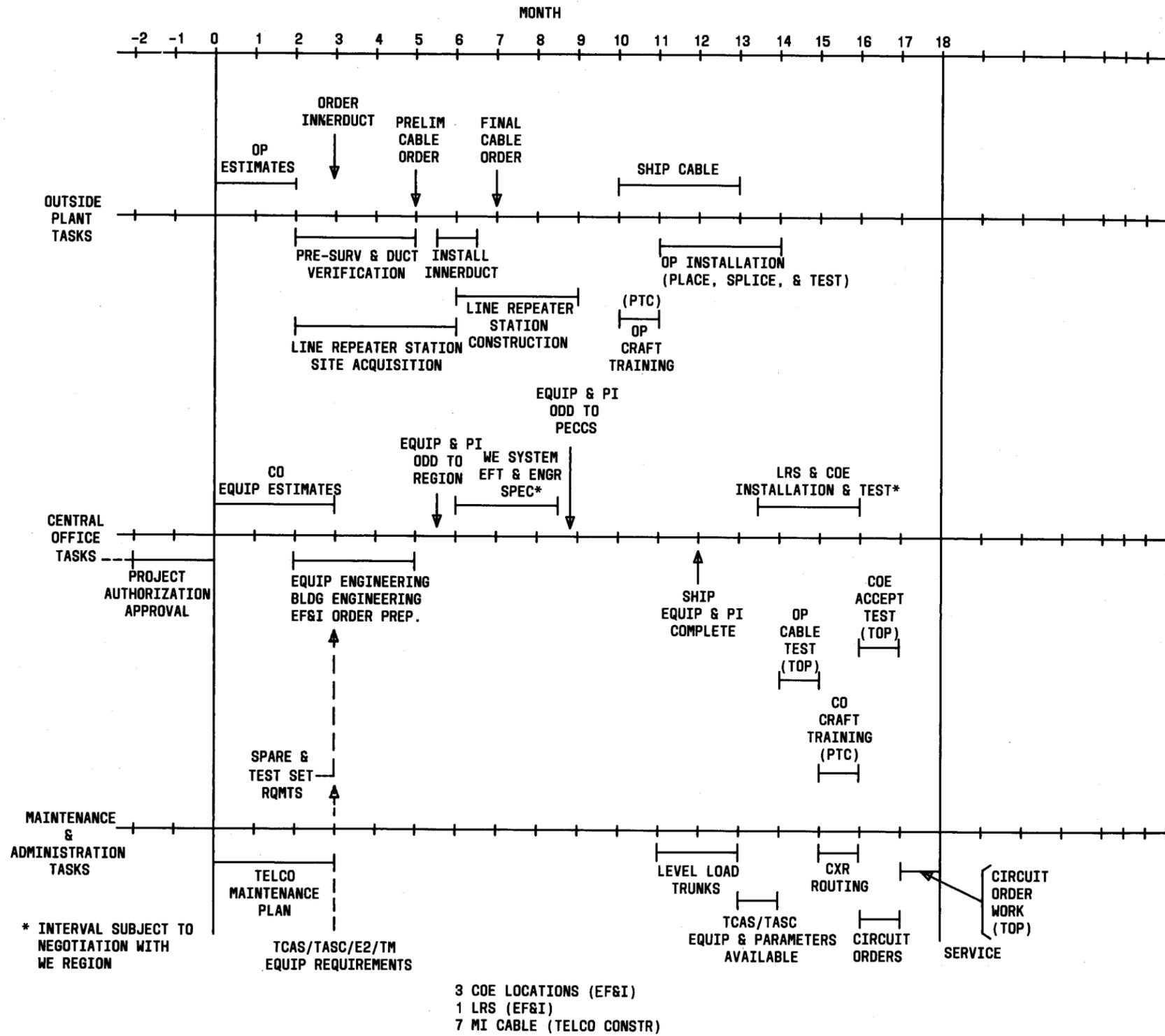
* THE MX3 MAY BE PART OF THE LTF
 † LIGHTGUIDE CABLE INTERCONNECTION EQUIPMENT
 ‡ CABLE ENTRANCE FACILITY
 § SEE SECTION 417-000-000
 ¶ THE MX3 MAY BE EQUIPPED FOR A LIGHTWAVE OR COAX OUTPUT BUT NOT BOTH AT THE SAME TIME

Fig. 5—T3 Digital System (44.736 Megabits per Second)



* SPAN TERMINATING FRAME
 † LINE FEED CONVERTER
 ‡ POWER SEPARATION FILTER
 § CABLE ENTRANCE FACILITY

Fig. 6—T4 Digital System (274.176 Megabits per Second)



3 COE LOCATIONS (EF&I)
 1 LRS (EF&I)
 7 MI CABLE (TELCO CONSTR)

Fig. 7—Example FT3 Initial Service Implementation Schedule