GENERAL PRINCIPLES OF FEEDER-DISTRIBUTION CABLE ENGINEERING (SAVE)

CONTENTS

1. GENERAL
2. SERVING AREA DESIGN CONCEPTS
3. SERVING AREA DESIGN METHODOLOGY
4. SAVE DESIGN CONSIDERATIONS
5. MAJOR PHASES IN PREPARING A SAVE DESIGN

FIGURE 1 - BOUNDED DESIGN AREA (LOAD COIL LIMITED)
FIGURE 2 - TYPICAL SERVING AREAS
FIGURE 3 - ENLARGED SERVING AREA

APPENDIX - SAVE DESIGN CHECKLIST

1. GENERAL

1.1 This section provides REA borrowers, consulting engineers, and other interested parties with information about the Serving Area Value Engineering (SAVE) concept in designing rural telephone plant. SAVE is a cable route design tool to determine the lowest cost design on an annual charge basis among alternate designs with different mixtures of cables, equipment, and construction schedules. Emphasis is placed on the use of fine gauge cable and pair gain devices (distributed and grouped analog station carrier, PCM subscriber carrier, electronic concentrators, and digital remote switching terminals) to reduce the total lifetime cost of serving rural subscribers. Future applications will see lightwave cable and associated electro-optical equipment compared to the fine gauge copper paired cable design.

1.2 The objective of the SAVE concept is to design a system that can be operated and expanded easily and economically for the next 10 to 15 years while providing for current and projected subscriber service needs.

1.3 SAVE is a tool that helps select the least cost solution to outside plant designs when there is a large degree of uncertainty about the subscribers or services on a route. It will be useful in areas of large or volatile growth, high subscriber density, areas with subscriber clustering, reinforcement of marginal plant, wire center relocation, multiparty upgrading, new exchanges, major construction projects etc. In areas with low or no growth, all single-party service, low density, etc., where only minor reinforcement of existing plant is planned, a detailed SAVE design would probably not be necessary.

1.4 The objectives of the SAVE method in the design of rural telephone systems are:

1.4.1 To provide flexibility in the use of feeder circuits to meet forecasted or unforecasted service demands.

1.4.2 To provide for growth in an orderly manner without extensive changes in cable plant.

1.4.3 To provide for the orderly introduction of pair gain devices.

1.4.4 To provide for improved plant layout and facilities to reduce plant administration, operation, and maintenance costs.

1.4.5 To provide uniform transmission treatment of distribution circuits.

1.5 Prior to the preparation of the system design, a long range plan will often have been prepared which considers subscriber growth and services, elimination of small central offices, introduction of digital, stored program control switchboards, interoffice trunking, etc. The long range plan will contain much of the data for a SAVE outside plant design.

1.6 The engineer will find helpful SAVE application and design information in the latest editions of the following REA TE&CM Sections:

TE&CM Section	Title
118	Plant Records System Serving Area Value Engineering for Rural Systems
231	Design Techniques for Serving Area Value Engineering
232	Transmission Design and Cost Considerations for Serving Area Value Engineering
629	Cable Plant Layout for SAVE
648	Serving Area Value Engineering (Physical Plant)

2. SERVING AREA DESIGN CONCEPTS

2.1 The SAVE concept divides the subscriber loop plant into two distinct categories (feeder or distribution) of outside plant . Feeder plant consists of the facilities between the central office switch and a specific interface point on the route toward the subscriber. These facilities can be physical pairs or transmission channels using radio, carrier, lightwave, or any other technology that may be appropriate. The specific interface point, called the Serving Area Interface (SAI), is where a cross-connection between feeder plant and distribution plant occurs. Facilities from the SAI to the subscriber location are called distribution plant. The distribution plant facilities at this time are only physical pairs. However, subscriber radio or cellular radio could be very well suited to distribution plant if cost effective and allowed by regulatory bodies. Lightwave cable may in the future also be used for distribution plant.

3. SERVING AREA DESIGN METHODOLOGY

3.1 The basic building block of the SAVE method is a bounded area called a Design Area (DA). The boundaries of the DA may be load points or other convenient points. The 5-year estimate and the estimated growth rate of subscribers within the DA are used as a basis for the design. Figure 1, "Bounded Design Area (Load Coil Limited)", illustrates a basic design area.

3.2 In low subscriber density areas a Serving Area (SA) is composed of one or more basic DA's. In high density areas, it may be necessary to subdivide a load coil bounded DA into several small DA's."

3.2.1 Subscribers in the SA are served by distribution pairs which are connected to feeder pairs at control points called "Serving Area Interfaces" (SAI's). The SAI is any plant housing used to cross-connect feeder circuits and distribution pairs. It may be an ordinary plant housing or a specially designed cabinet equipped with reenterable modules or blocks.

3.2.2 In actual practice, serving area boundaries will follow either natural boundaries, such as rivers and streams, or will follow man-made boundaries, such as interstate highways and utility right-of-ways. For convenience the serving area interfaces may be located at accessible and logical locations, such as cable route branches. The interfaces can also be located midway between load coils to allow proper voice frequency transmission on subscriber loops originating at carrier sites. Figure 2, "Typical Serving Area", illustrates typical serving areas.

3.3 If design areas have low to average rural subscriber densities, it will generally be found desirable to combine two to five tandem design areas into one enlarged serving area. Please refer to Figure 3, "Enlarged Serving Area".

3.3.1 Generally, when two to four design areas are combined in tandem to form an enlarged serving area, this increases the efficiency of the feeder circuits between the SAI and the central office and reduces the number of costly SAI's. Subscribers within the serving area are connected to the SAI by dedicated distribution cable pairs (preferably nonloaded). At the SAI the distribution pairs are connected to the feeder circuits by jumpers using terminal blocks or splicing connectors.

4. SAVE DESIGN CONSIDERATIONS

To implement the serving area concepts discussed in Section 2 and obtain the optimum economic flexibility, there are basic loss and resistance considerations that need to be kept in mind. The maximum subscriber loop loss permissible is 8 dB at 1000 Hz. The maximum resistance of the loop should be within the range of the central office switch. These considerations are outlined in the paragraphs that follow as general rules of thumb.

4.1 Cable Considerations

4.1.1 Consider <u>new</u> 26 gauge cable whenever a separate feeder cable (no access by station installers) of 200 pair can be justified if it will never be used for carrier and where no loops exceeds 4.6 km (15 kilofeet). Consider <u>new</u> 22 gauge cables only when subscriber loops extend more than 24 km (15 miles) from the central office.

4.1.2 When reinforcement of wire pair cables is required, use 24 gauge extensively. In most rural designs, when augmented with carrier, it results in the lowest annual cost per circuit.

4.1.3 Before completing the design, examine routes with reinforcing cables of 200 pair and larger for opportunities to reroute physical feeder pairs.

4.1.4 The installed cost per pair of cables smaller than 25 pairs is relatively high. To reduce the frequency of reinforcement of small pair size cables design them with low fill factors. Deferring a small reinforcing cable through use of carrier circuits until demand grows to require a larger reinforcing cable can be good engineering design. Initially, the use of carrier may not prove to be economical, but the movability and high salvage value of the reusable electronic equipment is a major factor in this design alternative.

4.1.5 The allowable length of a distribution pair is controlled by the distance from the central office for a physical circuit or the type of electronic pair gain equipment used to supply feeder circuits. A discussion of SAVE transmission and signaling criteria is contained in TE&CM Section 232.

4.2 Interface Considerations

4.2.1 The use of the SAVE design technique does not require the installation of SAI housings and components. Any designated points may be hardwired in standard pedestals or replaced by SAI type housings as required.

4.2.2 Try to avoid establishing an SAI with less than five physical feeder pairs. Where a concentrator with physical trunks is initially justified or the next reinforcement at the SAI is made with carrier or a concentrator, the provision of less than five physical feeder pairs may be considered.

4.2.3 SAI's should be located at intervals equal to or less than 18 kft (36 kft for areas in which backfeeding is acceptable). This will help facilitate the future introduction of digital services which will require nonloaded loops.

4.2.4 The SAI where distribution pairs and feeder circuits are to be cross-connected is a logical place for pair gain devices on the feeder circuits.

4.2.5 If pair gain equipment is added at an SAI, distribution pairs would then be connected to feeders derived by carrier channels. To provide flexibility with a minimum of engineering design later on, it is desirable to establish SAI's half-way between load points if conveniently possible. Otherwise, transmission limitations discussed in TE&CM 232, Paragraph 2, will have to be considered.

4.3 Pair Gain Considerations

4.3.1 Carrier, concentrators, and remote switches are pair gain devices. They can be used as alternatives to physical cable plant. As alternatives they may defer or eliminate reinforcement or additions to the paired cable plant.

4.3.2 Carrier and concentrators are located at loading coil section midpoints to improve feeder flexibility (physical to concentrator or carrier) and to facilitate the transfer of loaded and nonloaded cable pairs on the field side of the cross-connect point from physical feeders to distribution pairs. The use of section midpoints simplifies the transmission portion of the design. However, it is unlikely to have existing access at all half-loading section locations. Where half-load points are not practical the use of load coil locations provide an existing point of access. However, their use may limit the length of distribution loops or require the insertion of load coils half-way to the next load coil locations.

4.3.3 To provide flexibility, nonloaded feeder pairs reserved for carrier should be available at every SAI on each cable route. It is recommended that each SAI, where carrier is in use or expected, have a minimum of 10 percent of the pairs (up to 50 pairs) reserved for carrier systems.

4.3.4 The distribution pairs to be used with carrier derived feeder pairs are to be 24 gauge except when the subscriber density is so low that the extra reach achieved by using coarser gauge cable is necessary to achieve efficient grouped carrier fills.

4.3.5 To reduce operating costs, concentrators, carrier terminals, and carrier repeaters should be placed in a separate electronic housing adjacent to the housing for the cable cross-connections at the SAI location.

4.3.6 Pair gain equipment is movable plant with high salvage value.

4.3.7 Do not use existing air core cable pairs for carrier use unless transmission measurements have been made and are satisfactory.

4.3.8 There is no standardization in the cable make-up in unscreened cables for PCM capability. In contract construction, there is generally no way to select nonadjacent binder groups for increased crosstalk loss or prepare splicing instructions until the cable is delivered to the project. Placing repeaters at 1.4 km (4.5 kf) spacing increases the number of PCM systems possible in the nonscreened binder groups. Compartment type cable should be specified if carrier use is imminent.

4.4 Administrative Considerations

4.4.1 The purpose of the recommended assignments is to simplify the administration of assignments over the operating life of the cable plant. The <u>high count</u> pairs in a new combination feeder and distribution cable are assigned as distribution pairs. The <u>mid-count</u> pairs should be assigned as loaded feeder circuits. It would be desirable to assign the <u>low count</u> pairs to carrier, which would be unloaded pairs.

4.4.1.1 In a typical case, as growth occurs, the number of VF distribution pairs will need to increase. At first the VF distribution pairs are connected to the loaded feeder pairs until they are about to be exhausted. Assignments to the loaded feeder pairs will then be transferred to electronically derived feeder pairs freeing the loaded feeder pairs for more growth. The number of feeder pairs available will be increased primarily through application of electronically derived pair gain devices. As the feeder circuits reserved for carrier are exhausted, some of the loaded feeder pairs will be deloaded and reassigned as new carrier pairs. The basic assignment arrangement will then permit feeder circuit growth from low count up and distribution circuits from high count down.

4.4.1.2 This procedure is usually feasible in applying station carrier equipment which are two-wire systems operating at low frequencies. If four-wire PCM carrier is applied, the application rules of TE&CM 950 apply. However, they inhibit the use of low count pair assignments. Additional refinements in cable pair assignments can also be found in TE&CM Section 629.

4.4.2 In the design and construction of the first installation on a cable route using SAVE, the cables are to be sized to the nearest 25 pair multiple. Subsequent reinforcement cables are to be sized at the nearest 100 pair multiple.

4.4.3 Since standard PIC cable color code is based on groups of 25 pairs and subgroups of 5 pairs assign distribution and feeder physical pairs to the serving areas in multiples of 5 pairs.

4.4.4 For ease in troubleshooting as well as maintaining high carrier system fills, locate station carrier channels in groups to the maximum practical extent.

4.4.5 Retainable cable plant which passes through distribution housing and ready access enclosures should have existing pairs converted to distribution use.

4.5 Economic Considerations

4.5.1 PWAC cost studies are preferred for comparison of alternatives to first cost studies or annual charge studies. However, when the economics are obviously in favor of one alternative or noneconomic factors dictate the choice of one alternative then developing a PWAC analysis is unnecessary.

4.5.2 An economic study considers all major cost factors over the expected life of the project. It should include as a minimum factors for first cost, cost of money, taxes, depreciation, and maintenance.

4.5.3 Refer to the following sections for detailed guidance in preparing PWAC studies.

TE&CM	Title
218	Plant Annual Cost Data for System Design Purposes
219	Present Worth of Annual Charge Studies for System Design

5. MAJOR PHASES IN PREPARING A SAVE DESIGN

5.1 There are four major phases in preparing a SAVE design which will be briefly described below. Detailed, step-by-step examples of these four phases can be found in TE&CM 231.

5.2 Phase I begins with collection of data concerning reusable existing plant, five-year (existing plus potential) subscribers and probable new cable routings. Reinforcing cables tentatively required for five-year subscribers are determined throughout the exchange. Cost files for proposed cables, electronic equipment and miscellaneous hardware are created. The cost per load coil section of physical and pair gain feeder circuits are then determined. The load section where electronic feeders are equal to or less costly than physical feeders (on an annual charge basis) is called the break-even point. Phase I concludes by tentatively assigning the feeder pairs to physical or electronic circuits based on the lowest cost.

5.3 In Phase II probable locations for concentrators and/or subscriber carrier and cross-connect blocks are selected and the number of physical or electronic feeders is determined. Five-year subscribers beyond the break-even points are served by physical distribution plant to the SAI and electronic feeders to the CO.

5.4 Phase III selects specific locations for the Serving Area Interfaces inside the breakeven points and determines the number of physical and electronic feeders. Five-year subscribers beyond the breakeven point are served by carrier and/or concentrators. Therefore, the number of cable pairs between the breakeven point and the central office can be reduced from what was tentatively chosen in Phase I. This will usually allow smaller reinforcing cables than those chosen in Phase I.

5.5 For Phase IV the engineer evaluates the resultant design from a total overall view and makes final adjustments as necessary for practical reasons. For example, the locations of SAI's or serving area boundaries may be adjusted. This final stage should review the considerations in Section 4 plus any unique local considerations and make adjustments if appropriate.

5.5.1 In making a final decision on the number and assignment of physical feeder pairs consider that (1) there should be adequate spare carrier feeder pairs; (2) carrier pairs in cables of 25 pair and above should be capable of PCM operation; (3) spare pairs close to the central office should remain nonloaded; and (4) reinforcing cable pair size changes should only be made at existing or future SAI's, major road intersections, or major cable branch points.

5.5.2 In making final decisions on the type of analog or digital carrier to be selected, the engineer should consider (1) the number of electronic equipment housings required; (2) the number of intermediate power supplies required; (3) the ease of meeting unanticipated growth; (4) the pair gain advantage; (5) the operating advantages; and (6) the cost of carrier.

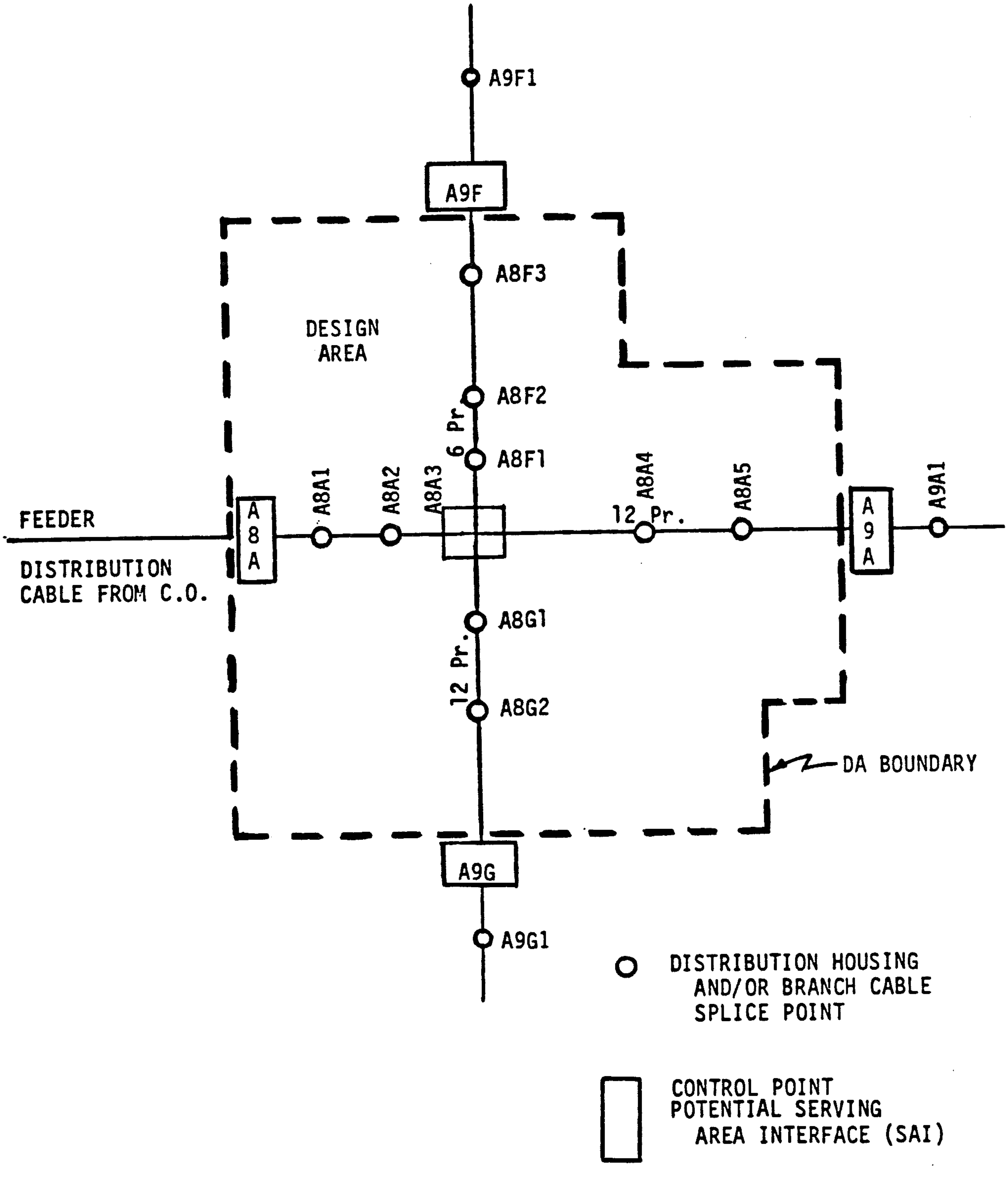
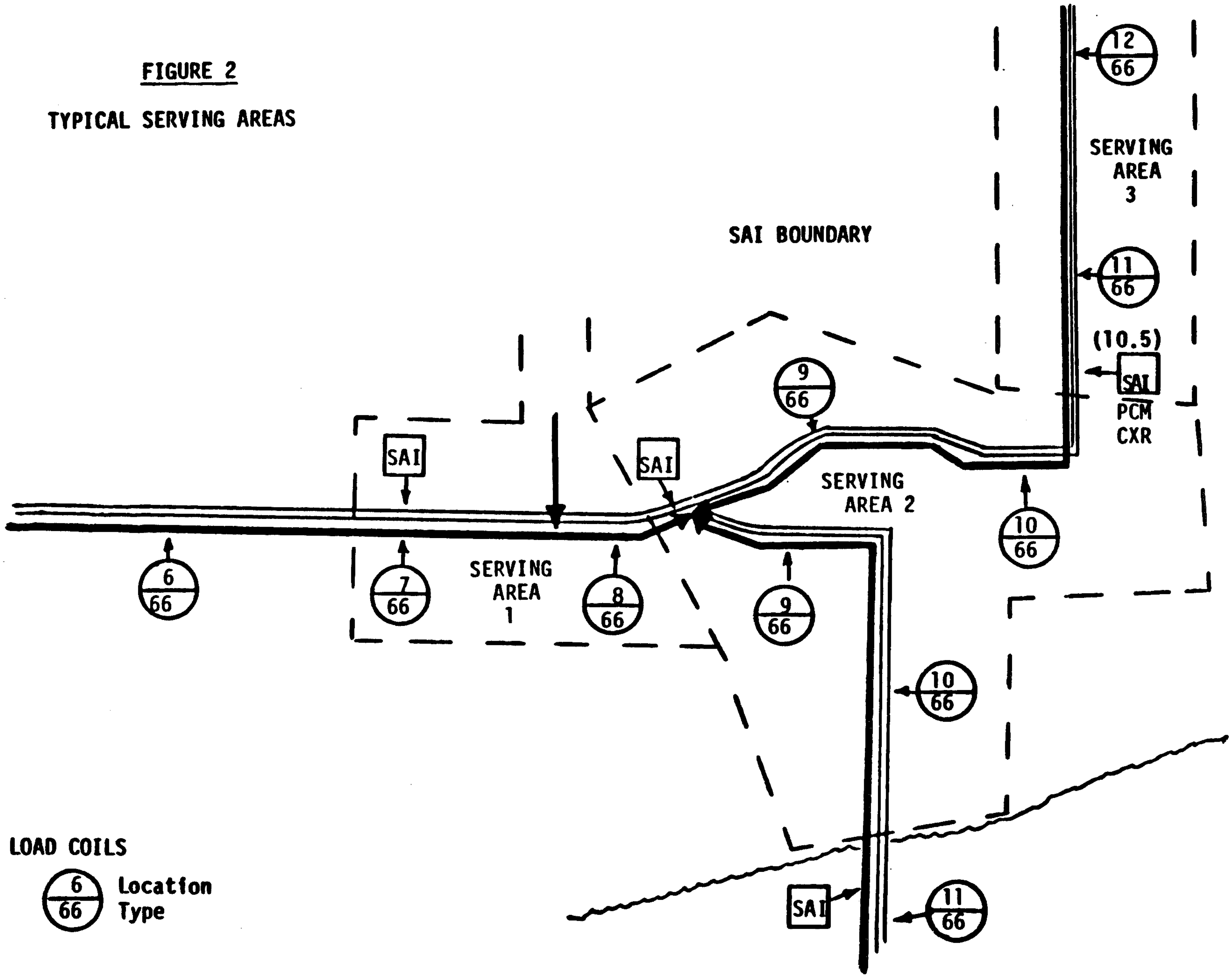


FIGURE 1

BOUNDED DESIGN AREA
(LOAD COIL LIMITED)

FIGURE 2

TYPICAL SERVING AREAS



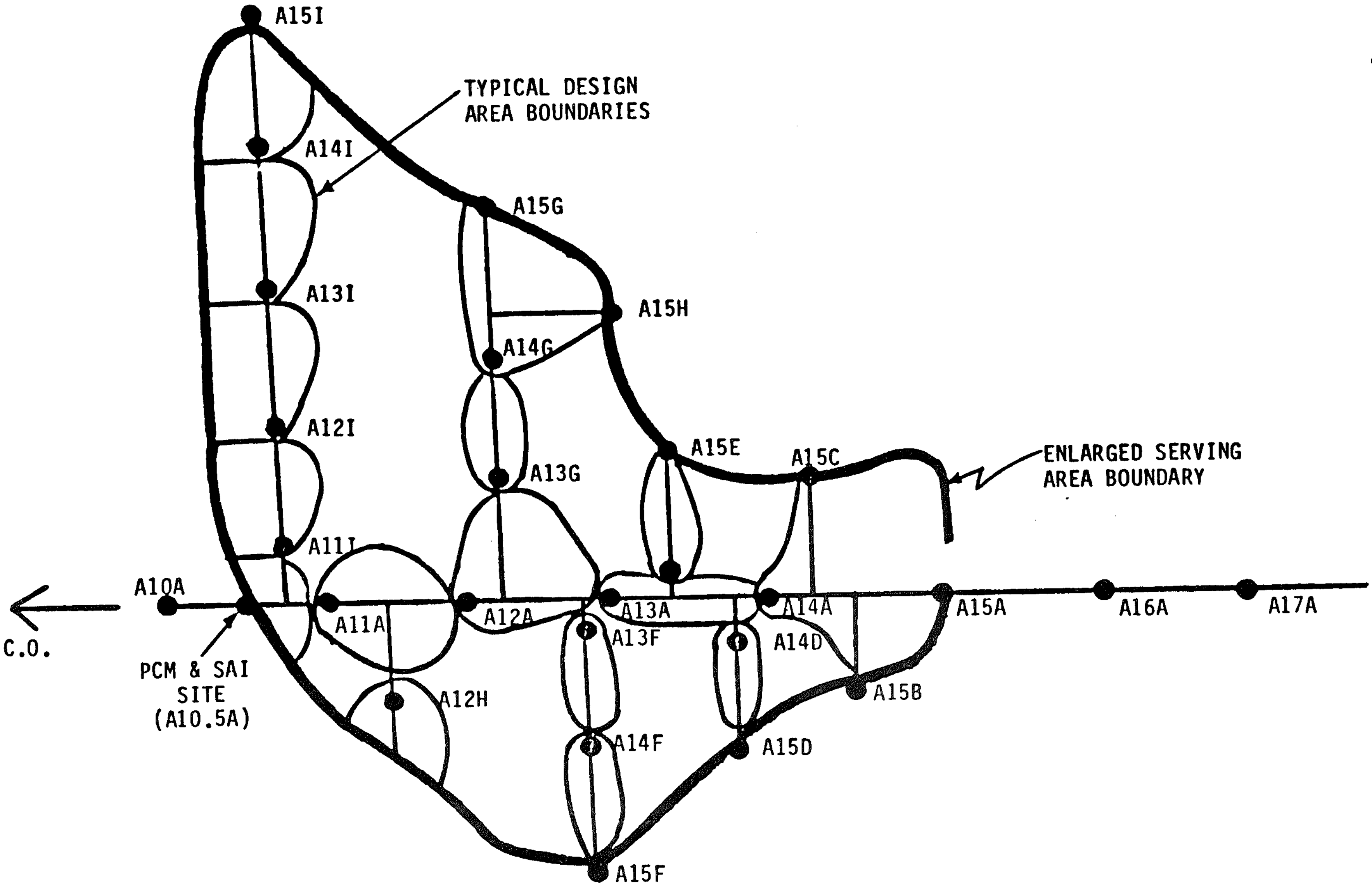


FIGURE 3

ENLARGED SERVING AREA

APPENDIX I

CHECKLIST FOR REVIEW OF SERVING AREA VALUE ENGINEERING DESIGNS

Item	Check YES	Check NO	Check NA
1. Unit Cost and Annual Charge Data			
1.1 All unit first costs for cable and electronic equipment have been included with the design.			
1.2 All of the components for developing annual charge factors for cable and electronic equipment have been included with the design.			
1.3 A cable fill factor table developed in accordance with TE&CM Section 231 has been used to size cables and is presented with the study.			
1.4 Are per circuit costs for physical, distributed and grouped station carrier, and PCM subscriber carrier shown on the SAVE design worksheets?			
1.5 Are per circuit costs for any other type of pair gain plant considered shown on the worksheets?			
1.6 A table of carrier equipment cost data adjusted for annual charges and voice frequency equipment costs was used to develop per circuit costs and is included with the design.			
1.7 A cost algorithm was used to develop the per circuit costs.			
1.8 Is an explanation of the cost algorithm included in the design?			
2. Transmission Design Parameters			
2.1 Have the transmission design parameters used in preparing the SAVE design been included?			
2.2 Loading system type			
2.2.1 D-66 ______			
2.2.2 H-88 ______			

Item	Check		
	YES	NO	NA
2.3 Voice frequency equipment resistance			
2.3.1 Ohms per load coil ________.			
2.3.2 Ohms per central office voice frequency repeater ________.			
2.3.3 Ohms per field mounted voice frequency repeater ________.			
2.4 Maximum subscriber loop ohm limits (excluding telephone set):			
2.4.1 Central office ________.			
2.4.2 Distributed station carrier ________.			
2.4.3 Grouped station carrier ________.			
2.4.4 PCM subscriber carrier ________.			
2.4.5 PCM subscriber line concentrators ________.			
2.4.6 Remote switching terminals ________.			
2.4.7 Other (specify) ________________ ________.			
2.5 Central office to subscriber carrier or pair-gain terminal loop ohm limits:			
2.5.1 Distributed station carrier ________.			
2.5.2 Distributed station carrier with remote power ________.			
2.5.3 Grouped station carrier ________.			
2.5.4 Grouped station carrier with remote power ________.			
2.5.5 Subscriber line concentrator VF trunk type ________.			
2.5.6 SxS remote switching terminal VF trunk type ________.			
2.6 PCM span lines			
2.6.1 PCM span line will be on:			
2.6.1.1 Existing cables.			
2.6.1.2 New nonscreened cables.			
2.6.1.3 New screened cables.			

Item	Aerial	Buried	Check YES	Check NO	Check NA
2.6.2 Design parameters					
2.6.2.1 Design temperature	____	____			
2.6.2.2 Maximum repeaters spacing on:					
2.6.2.2.1 Existing cable	____	____			
2.6.2.2.2 New nonscreened cable	____	____			
2.6.2.2.3 New screened cable	____	____			
2.6.2.3 Repeater current consumption ________.					
2.6.2.4 Power source voltage ________.					
2.7 Are station carrier repeaters spaced at 35 dB @ 20° C (68° F)?					
2.8 Cable resistance and attenuation 24 gauge @ 20° C (68° F)					
	Aerial	Buried			
2.8.1 Cable resistance	____Ω/____	____Ω/____			
2.8.2 Cable attenuation					
2.8.2.1 1 K Hz	____dB/____	____dB/____			
2.8.2.2 112 K Hz	____dB/____	____dB/____			
2.8.2.3 For PCM based systems on 24 gauge cable					
772 K Hz Cable attenuation	____dB/____	____dB/____			
At design temperature of:	____	____			

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