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A Computer Study for the Allocation of Channels and the Placement of Transmitters for 2500 MHz Fixed-Station Service in a Metropolitan Area Containing Many Eligible Applicants for Licensing.

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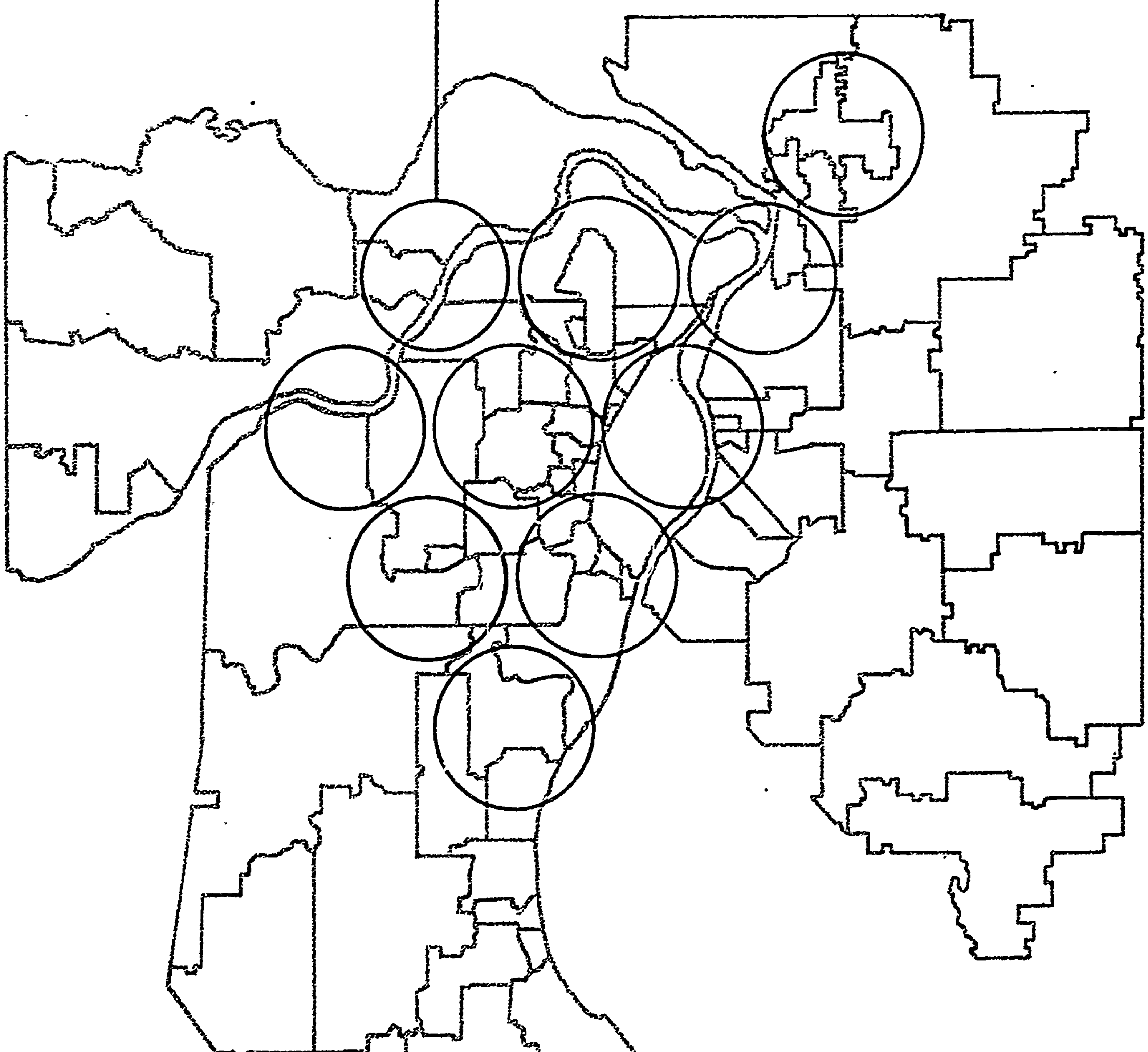
The North Circle Project demonstrates the feasibility of a multi-purpose, multi-channel television network attained through cooperative efforts of an educational community. The study was necessitated by the likelihood of congestion of airwaves on educational channels in urban areas. In 1966 the Federal Communications Commission called a meeting of educators, television specialists, and equipment manufacturers to testify to the problem. The development of this computer study for the future assignment of 2500 megacycle channels to eligible users in the Greater St. Louis area was an evantual result of this meeting. The body of the report describes a computer program designed to generate the optimal positions for transmitting and receiving units in regions of high density transmission. The received signal quality and interference levels tolerable are further examined. Descriptions of the relevant variables that must be considered are highly detailed. Flow charts of all processes described are included in the computer study. (RP)

NORTH CIRCLE PHASE b REPORT



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COOPERATING SCHOOLS A-V CORPORATION
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Ad Hoc Committee on
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Effective May, 1967

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PREFACE

Although Instructional Fixed Television Service is a relatively new service, authorized, defined and regulated by the Federal Communications Commission, it has become the focal point of much attention since the North Circle staff published its Phase A report in 1965. At this time a small and relatively unused portion of the airwaves was assigned for instructional and administrative uses, and the North Circle Project demonstrated the feasibility of a multi-purpose, multi-channel network to be accomplished through cooperative efforts of an educational community. As eligible applicants applied for channel allocations in conformity with the FCC criteria, it became apparent that 31 channels of telecasting were not without limitation. As generous a figure as it might seem (31 channels for the exclusive use of those engaged in formal instruction in a given area), congestion of the airwaves and demand which quickly exceeded supply in some areas became a reality.

Early in 1966 the Federal Communications Commission called a meeting of equipment manufacturers, educators, television specialists, and other interested parties. The purpose of this Washington session was to see if there was the likelihood of saturation of this spectrum in urban areas. The underlying assumption seemed to be, that if such overdemand or saturation of spectrum seemed likely, something should be done to eliminate or at least minimize the danger. Testimony at these hearings was diverse and revolved around plans, aspirations, or a prognostication which tended to show an active future for ITFS users, especially in the population centers of the nation.

Accepting this premise, the Federal Communications Committee established a national committee for full development of the Instructional Television Fixed Service (frequently called "2500 megacycle television" because of the frequency range it occupies). This committee, composed of 22 educators interested in

instruction by television, has met several times and has published, in conjunction with the Division of Educational Technology, National Education Association and the Consumer Products Division, Electronic Industries Association, the manual "ITFS, What It Is...How To Plan" as a guide for potential users of 2500 megahertz.

At various times and in various manners, the Federal Communication Commission has made clear to this committee the following facts:

1. The FCC has neither the time, personnel, or authority to adjudicate between competing applicants for use of telecasting frequencies which may become short in supply in a given area.
2. The FCC hopes that local committees might be formed in potential saturation areas which would plan the development of ITFS in these areas in a manner which would make possible the greatest number of simultaneous transmissions in the allotted band by cooperative and efficient planning.
3. The FCC would desire such planning to involve the potential applicants in such a manner that it would be possible to minimize conflicts and competition among applications for the available supply of transmitting frequencies.
4. The FCC would like members of the national committee for full development of ITFS to form regions, foster local committees (having the same purpose as the national committee) and create planning bodies and plans which, by their very nature, would be acceptable and self-enforcing in areas where saturation is likely.

The intent of the Commission thus seems clear. It is to provide multichannel communications paths for the teaching institutions in order to meet the challenges of modern education. The present rules require that each applicant design his equipment system to minimize interference with other applicants in

concurrent or adjacent areas. This can be accomplished by shaping antennae for transmitting, by using minimum required power to develop plans and/or reacting to developed plans and site transmitters for given clientel-reception areas in an efficient manner.

Although the North Circle plan for processing data honors both technical and geographic information, it does not comprehend political considerations. A technically desirable point for signal emanation may be politically undesirable or impossible. Such would be the case where siting a transmitter in mid-river could be technically advantageous for permitting maximum signal generating but obviously would be impractical for political and economic reasons since ownership and construction techniques would be too thorny to consider.

Even if the proposed planning tool were to show how all 171 eligible applicants in the St. Louis Area could activate four non-interfering transmitters each, this total accomplishment of such a plan is unlikely. It might be a basic pattern toward which those who would activate transmitters should strive, but it also represents the pattern from which activators must necessarily deviate. This deviation represents the political, economic, or psychological reasons employed in system implementation. Yet, a theoretically perfect plan, modified by numerous practical deviations from such a plan, would still seem preferable and more efficient than random placement or independent and minimal-thought planning.

Presuming that the North Circle planning tool would not be adequate to provide the required number of transmitters to meet actual future demand, or that deviations from this plan would reduce the number of transmitters to create a supply unequal to demand,there still must be some allocation plan to accompany any siting plan. Allocation means, in this sense, the apportioning of a resource

in inadequate supply to meet a given demand of the eligible applicants. The question then centers on priority. If enough transmitters can not be sited in a non-interfering manner to satisfy the demanding applicants, which applicant will be awarded how many channels? We have now a political rather than a technical question.

Even though the program presented in this report has not yet been applied to St. Louis (or any other environment), it is assumed that each area must be prepared to contend with overdemand and inadequate supply. Even with the best planning, and certainly if no planning at all occurs, the eventuality of saturation must be anticipated. Therefore, the North Circle research staff has addressed itself to allocation plans as well as siting plans.

From the start, it was assumed that the plan itself (allocation or siting plans) must be self-enforcing. Since the Federal Communications Committee is committed to honoring applicants on a first-come-first-served basis and has no power to force any authorized applicant into a restrictive position in comparision to another legitimate applicant, the applicants who do approach the FCC for permission to activate channels must do so with self-restraint. This can be achieved through enlightened self-interest or under the influence of social pressure by peer school-units whose favor is esteemed by the applicant. Therefore, both siting and allocation plans must be satisfying to all applicants to the extent that all are willing to abide by such proposals.

It is hoped that development of siting plans and allocation plans which eliminate surprise moves by neighbor schools and which give applicants more assurance of stable, continuing conditions and more channels of communication would be preferred over non-planning. This advantage could be a basic controlling factor, thus eliminating the need for restrictive, negative action. In order to pilot such action, the Greater St. Louis Ad Hoc Committee on ETV (page iii) has now been established to develop and discuss criteria which might

be employed in allocating transmitting rights among the 171 applicants in the study area. It represents the concerns of the educational community, both in Missouri and Illinois, which has a stake in the future allocation of channels by the FCC. It has also been charged with developing the least argumentative and most mathematically advantageous basis for the future assignment of 2500 megacycle channels to eligible users in the Greater St. Louis area.

1. INTRODUCTION

The program outlined in this section is intended for use in the design and analysis of large-scale 2500 mc. instructional television networks. A network will consist of transmitting locations spaced throughout a metropolitan area, each location broadcasting on several frequencies and serving many surrounding receivers.

Transmitter spacing, received signal quality, and interference levels must be investigated to insure that a network provides satisfactory service to all its users. This program can perform any or all of the following tasks in such an investigation:

1. Compute receiver noise level and if desired, select a receiving antenna to provide a specified signal/noise ratio at the receiver.
2. Compute receiver signal strength from parent or owning transmitter.
3. Find the minimum clearance along the line-of-sight path from parent transmitter to receiver, or compute receiver antenna height necessary to provide acceptable clearance.
4. Output for subsequent plotting the terrain profile along the line-of-sight path from parent transmitter to receiver.
5. Identify any obstacles from an input list that may block or distort a signal along the above line-of-sight path.
6. Determine what interference will exist from surrounding transmitters.
7. If interference is severe (as defined by the user) investigate the line-of-sight path from an interfering transmitter to the receiver to determine if intervening ter-

rain will attenuate interference effects.

8. Output for subsequent plotting the terrain profile along the line-of-sight path from interfering transmitter to receiver.

As measures of the suitability of transmitting location characteristics, the program outputs an average of the receiving antenna heights computed for receivers served by a location, and a list of the number of receiving antennas of each type selected to provide acceptable received signal quality.

The text, figures and flow charts are sufficiently detailed to allow interested readers to grasp the ideas involved and devise their own additions, deletions or improvements.

2. Program Data - General

Data for the program is in four sections, (1) control cards, (2) antenna data, (3) transmitter data, and (4) receiver data. Different types of cards in the deck are identified by alpha-numeric labels in their first columns. Particular cards that may appear in each section are discussed briefly below. More detailed descriptions of each card are in the explanations of input procedures for the four data deck sections.

Control

GClb, GC2b and GC3b - three unique control cards which can define general parameters, tolerances and reference values that control execution of the program.

SCbb - a special control card (the deck may contain several of these) which permits exceptions to general control values to be made for a specific receiver, or for a group of receivers

owned by a particular transmitter.

Antenna

Abbb - a card containing azimuth-gain pairs to be stored in a table describing an antenna's gain characteristics through 360°.

Transmitter

Xbbb - a card describing characteristics of a transmitting location XFRb - if more than one frequency is broadcast from a transmitting location, a set of these cards (immediately following the location to which they pertain) describe the polarization, transmitted power and antenna height of each frequency.

Receiver

Rbbb - a card describing characteristics of a receiver.

3. Program Control

The program groups receivers according to the transmitting location serving them, either as specified by the user or by default (assignment to the nearest transmitter). The program then moves from group to group in sequence, processing all receivers in each group before proceeding to the next. The control scheme presented allows the user to specify in general the computations and tolerances he desires, and to make detailed exceptions for particular receivers or groups of receivers.

Defined below are 24 program variables subject to the user's control (others may be added as desired). The variables are related within the program to three sets of arrays (see figure 1), each set consisting of an integer and a decimal section:

1. the "general" arrays INTG and DECG, single-subscripted
2. the "current" arrays INTC and DECC, single-subscripted, and
3. the "special" arrays INTC and DECS, double-subscripted.

Definitions:

NCOMP the type of electronic computation desired

Value	meaning
-1	omit computation
0	no action
1	signal strength and noise at receiver
2	interference at receiver
3	do both above computations

NTOPO the topographic computation desired

Value	meaning
0	no action
1	owner transmitter line of sight to receiver
2	interfering transmitter line of sight to receiver
3	do both above computations

NPLOT plotting desired

Value	meaning
0	no action
1	organize for plot the topographic computation for owner transmitter
2	organize for plot the topographic computation for interfering transmitter

NOBST the obstacle checking desired

Value	meaning
0	no action
1	search for obstacles on owner transmitter line of sight to receiver

NXTAB	size of topography file (X dimension)
NYTAB	size of topography file (Y dimension)
NTTAPE	number of device on which topography file is stored
NOTAPE	number of device on which obstacle file is stored
NPTAPE	number of device on which plotting data is written
FZCL	fresnel zone clearance - feet
DISTO	transmitters beyond this distance from a receiver are not checked for interference effects - miles
RSNRAT	desired receiver signal to noise ratio for selecting receiving antenna - decibels
RNBW	receiver noise band width - megacycles
TOPDBA	absolute interference ratio below which topography to interfering transmitter is checked for possible screening effects - dbm
TOPDBR	signal-to-interference ratio below which topography to interfering transmitter is checked for possible screening effects - decibels
TPWR	transmitter broadcast power assumed if none is given-watts
RNSE	receiver noise figure assumed if none is given - decibels
TAHGT	transmitter antenna height assumed if none is given - feet
HSNDB	signal to (interference + noise) ratio for receiver above which a "high" flag appears in printout - decibels

LSNDB signal to (interference + noise) ratio for receiver above which a "low" flag appears in printout - decibels.

DX distance between topographic data points in X direction - miles

DY distance between topographic data points in Y direction - miles

X factor in exponent of fading margin equation

ERADF factor for increased earth radius due to signal refraction in atmosphere.

Initial values for all 24 variables are loaded automatically in INTG and DECG by the program before execution. Variables whose values will remain constant during execution of the program are made equivalent to the last several positions in INTG (NXTAB through NPTAPE) and DECG (TPWR through ERADF). If an automatically stored value for this type variable does not meet the user's needs, he can enter the desired value (which must be non-zero) in the proper field on control card GC1,GC 2 or GC 3 and the desired value will be in effect throughout execution, replacing the automatically stored value in some position of INTG or DECG. Five integer and nine decimal variables of this type are shown in Fig. 1.

The other four integer variables (the computation parameters) and six decimal variables can be changed during execution of the program as it arrives at a group of receivers, or a single receiver, for which some special request (an SC or special control card) has been made. These variables are made equivalent to the four integer positions in INTC and the six decimal positions in DECC, the "current" arrays. Values from corresponding positions in the "general" arrays are in INTC and DECC until some special request

Fig. 1 - PROGRAM CONTROL SCHEME

GENERAL — CURRENT — SPECIAL

INTG(L)

Suggested automatically stored initial value

Suggested card for change

Suggested field on card

L				EQUIVALENCE
1	0	GC1	1	
2	0	GC1	2	
3	0	GC1	3	
4	0	GC1	4	
5	0	GC2	1	NXTAB
6	0	GC2	2	NYTAB
7	0	GC2	3	NTTAPE
8	0	GC2	4	NOTAPE
9	0	GC2	5	NPTAPE

INTC(L)

	L
NCOMP	1
NTOPO	2
NPLOT	3
NOBST	4

INTS(K,L)

Suggested field on K^{th} SC card

L	
1	3
2	4
3	5
4	6
5	1
6	2

DECG(L)

1	30.0 ft.	GC2	8	
2	16.0 mi.	GC1	5	
3	46.0 db	GC1	6	
4	6.0 mc.	GC3	1	
5	0.0 db	GC3	2	
6	0.0 db	GC3	3	
7	10.0 watts	GC3	4	TPWR
8	8.5 db	GC3	5	RNSE
9	100.0 ft.	GC3	6	TAHGT
10	50.0 db	GC1	7	HSNDB
11	40.0 db	GC1	8	LSNDB
12	0.0 mi.	GC2	6	DX
13	0.0 mi.	GC2	7	DY
14	.5	GC3	7	X
15	1.333	GC2	9	ERADF

DECC(L)

FZCL	1
DISTO	2
RSNRAT	3
RNBW	4
TOPDBA	5
TOPDBR	6

DECS(K,L)

1	7
2	8
3	9
4	10
5	11
6	12

(the Kth SC card) must be honored. At this point <u>all four</u> corresponding integer values from INTS and <u>all non-zero</u> corresponding decimal values from DECS are transferred to INTC and DECC, respectively. After processing to which a special request pertains is completed, values from "general" (or another "special" -see below) are restored to "current".

The following points should be noted with respect to the control procedure:

1. On a special control card all four integer variables (the computation parameters) must be specified, not just those that differ from the general controls. However, only those (non-zero) decimal variables on the card which differ from the general controls need be entered.
2. A special request for a receiver supercedes a special request for its group, which in turn supercedes the general controls.
3. Conflicts may occur within a given set of four integer computation parameters. For example, plotting data cannot be output without prior performance of the topopgraphy computations. These conflicts are resolved during execution. If desired a message can be generated about any conflict and the means by which it was resolved.
4. The value -1 for NCOMP is used only on SC cards. It causes a receiver or receiver group to be bypassed completely.
5. Position INTS (K,5) shown in figure 1 is the positive integer label of the transmitter owning the group to which the special controls apply. Position INTS (K,6) is the positive integer label of the receiver within the group, if the controls deal with a specific receiver.

4. Input Method - General

Input for the program is thoroughly scanned. Experience has shown that the method used pinpoints at once data errors which might otherwise go undetected through the entire course of an analysis employing a program. Points in the flow diagrams at which errors are detected, and the nature of the errors, are clearly indicated. Analysts and programmers implementing the program can incorporate in it an error subroutine and furnish to the subroutine from each error point arguments describing the error in detail. The offending data card can be printed with the same format regardless of the stage to which input has progressed.

A rash of errors usually indicates some fundamental mistake in filling out fields or ordering the deck. The program design includes an error counter IERR and a maximum error limit MAXR which can be used to cut short a large list of probably redundant error messages. This feature can be omitted if not desired, or MAXR can be set arbitarily large.

Each data card is read as an alphanumeric WORD (first four columns) and an alphanumeric array A of length 68, each word in A corresponding to a remaining card column from 5 through 72. The card type is found by comparing WORD to a single-subscripted array RW (see figure 2). The number of fields to be scanned and transformed in array A for each card type is obtained from array NFLD. The starting and ending points in array A of each field are taken from arrays NFST and NLST (double-subscripted b card type and field). The scanning and transformation are accomplished by three processes.

Fig. 2 - ARRAYS USED IN PROCESSING INPUT

Single - Subscripted Reference Arrays

RW(I)	NFLD(I)
R	
X	
XFR	
A	
SC	12
GC1	8
GC2	9
GC3	7
END	

Double - Subscripted Reference Arrays
Example is SC card below (I = 5)

NFST(5,K)	NLST(5,K)	NTYPE(5,K)	NSTO(5,K)
2	4	1	5
6	8	1	6
10	11	1	1
13	13	1	2
15	15	1	3
17	17	1	4
19	24	2	1
26	31	2	2
33	38	2	3
40	45	2	4
47	52	2	5
54	59	2	6

Card Layout of SC Card — Control Data

		2 4	6 8	10 11	13	15	17	19 24	26 31	33 38	40 45	47 52	54 59	Position in A (NFST, NLST)
SC bb		IXLBL	IRLBL	NCOMP	NTOPO	NPLOT	NOBST	EZCL	DISTO	RSNRAT	RNBW	TOPDBA	TOPDBR	Variable Name
		1	2	3	4	5	6	7	8	9	10	11	12	Field
		6 8	10 12	14 15	17	19	21	23 28	30 35	37 42	44 49	51 56	58 63	Card Column

1. FDEFN, which locates the exact position of the number within the field.
2. INTBLD, which transforms positive integers, and
3. DECBLD, which transforms decimal numbers of either sign.

The nature of the number in each field is in array NTYPE. Array NSTO contains the exact subscript value to be used for storing the transformed number in some array, and it is used in processing the cards in the control section of the data.

Note that the double-subscripted arrays are a ragged table with 8 rows and as many columns as the largest number of fields to be processed among the 8 card types in the deck. In the suggested formats the SCbb and Rbbb cards both contain 12 fields.

Entries in the above arrays are loaded automatically in the program before execution (by means of DATA statements if FORTRAN is used). Other reference values, mentioned in the input sections to which they apply, are established in the same manner. It is assumed that data areas which should be initialized to zero will be recognized by the reader.

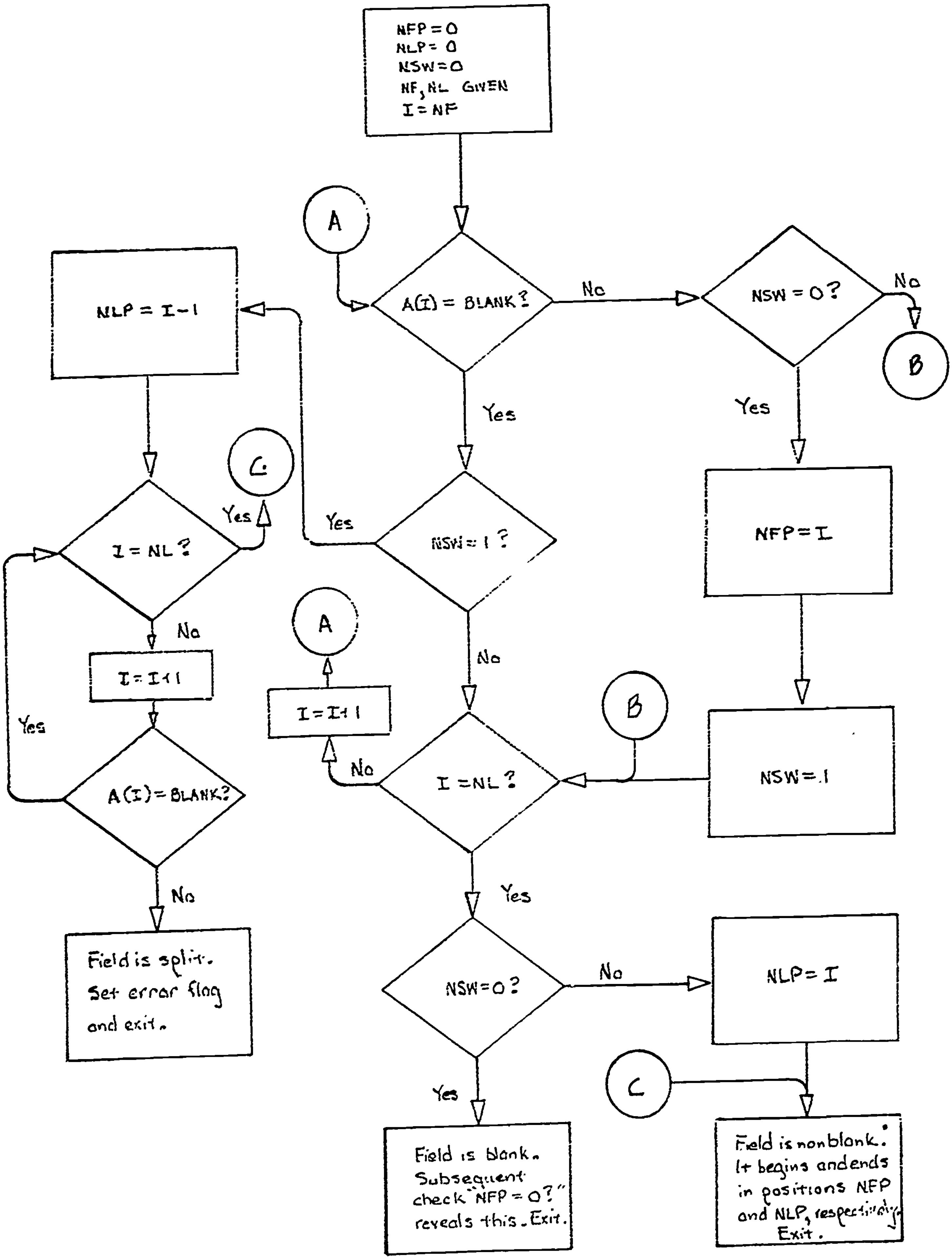
Figure 3 shows one of the processes used in treating input data. This process determines the beginning (NFP) and ending (NLP) indices of any contiguous string of non blank characters existing in array A between limiting positions NF and NL. The string will be converted to a number in subsequent processes. If two such strings exist within the limiting positions, an error flag is set to indicate an embedded blank.

4.0.1 Process FDEFN

Definitions

A a single subscripted array, each word of which contains one column of a data card read in with alphanumeric format.

Fig. 3 - PROCESS FDEFN



BLANK a reference word containing an alphanumeric blank.

NF index of the first word in array A which is to be tested.

NL index of the last word in array A which is to be tested.

NFP index of the first non blank word in array A among tested words.

NLP index of the last non blank word in array A among tested words.

NSW a switch which is 0 if the word previously tested was blank, 1 otherwise.

INTBLD, shown in figure 4, follows FDEFN for fields on input cards with NTYPE = 1 (see figure 2)

This process converts a contiguous string of alphanumeric characters in array A to an integer. Proceeding right through the string (index I), from A (NFP) to A (NLP) each character is tested against reference array ANUM. If a match is found (between A (I) and ANUM (J)) the value INTG accumulated so far is multiplied by !0 and the index J decremented by 1 is added to INTGR. If no match is found, the character being tested in A (I) is not an integer and an error exists.

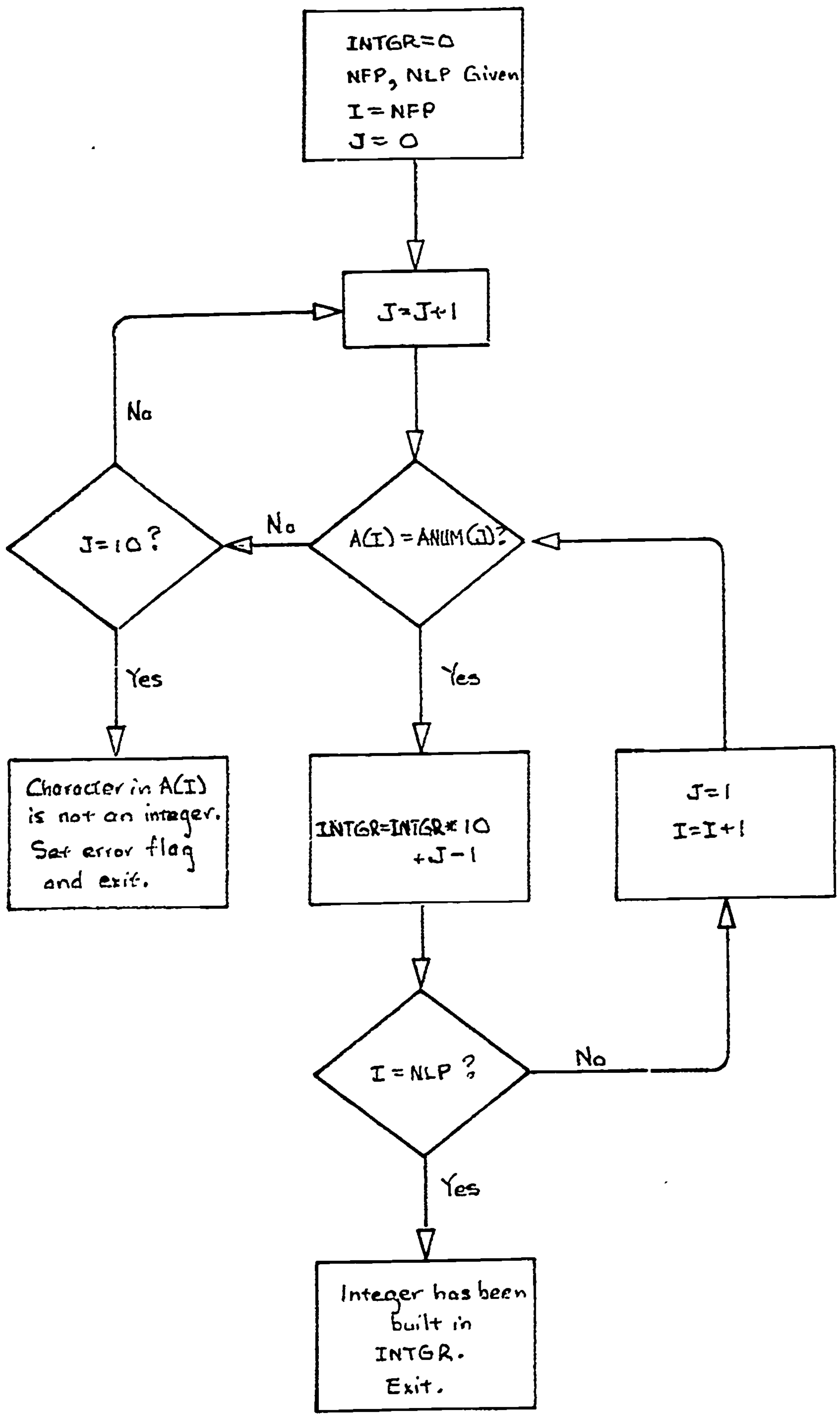
4.0.2 Process INTBLD

Definition

A a single subscripted array, each word of which contains one column of data card read in with alphanumeric format.

ANUM a single subscripted array of !0 reference words, each of which contains the integer (in alphanumeric format)

Fig. 4 - PROCESS INTBLD



with value one less than the word index (A (1) = 0, A(2) = 1, A(3) = 2, etc.)

NFP index of first word in array A to be converted.

NLP index of last word in array A to be converted.

INTGR value of converted integer

DECBLD, shown in figure 5, follows FDEFN for fields on input cards with NTYPE = 2.

This process converts a contiguous string of alphanumeric characters in array A to a decimal number VNUM. Proceeding right through the string from A(NFP) to A(NLP) the first characters are tested for sign and/or decimal. If a decimal precedes any integer characters, the right-hand side of the number is integerized and converted to decimal. Otherwise, the decimal point in the string is located and characters to the left and right of it are integerized and converted to decimals VLEFT & VRGHT, respectively. If no decimal point can be located in the string, an error exists. Finally, the two decimal values are combined with sign factor XSIGN, VRGHT being adjusted by the proper power of !0.

4.0.3 Process DEGBLD

Definitions

A as in prev. processes

DECIMAL reference word containing alphanumeric decimal point

PLUS reference word containing alphanumeric plus sign

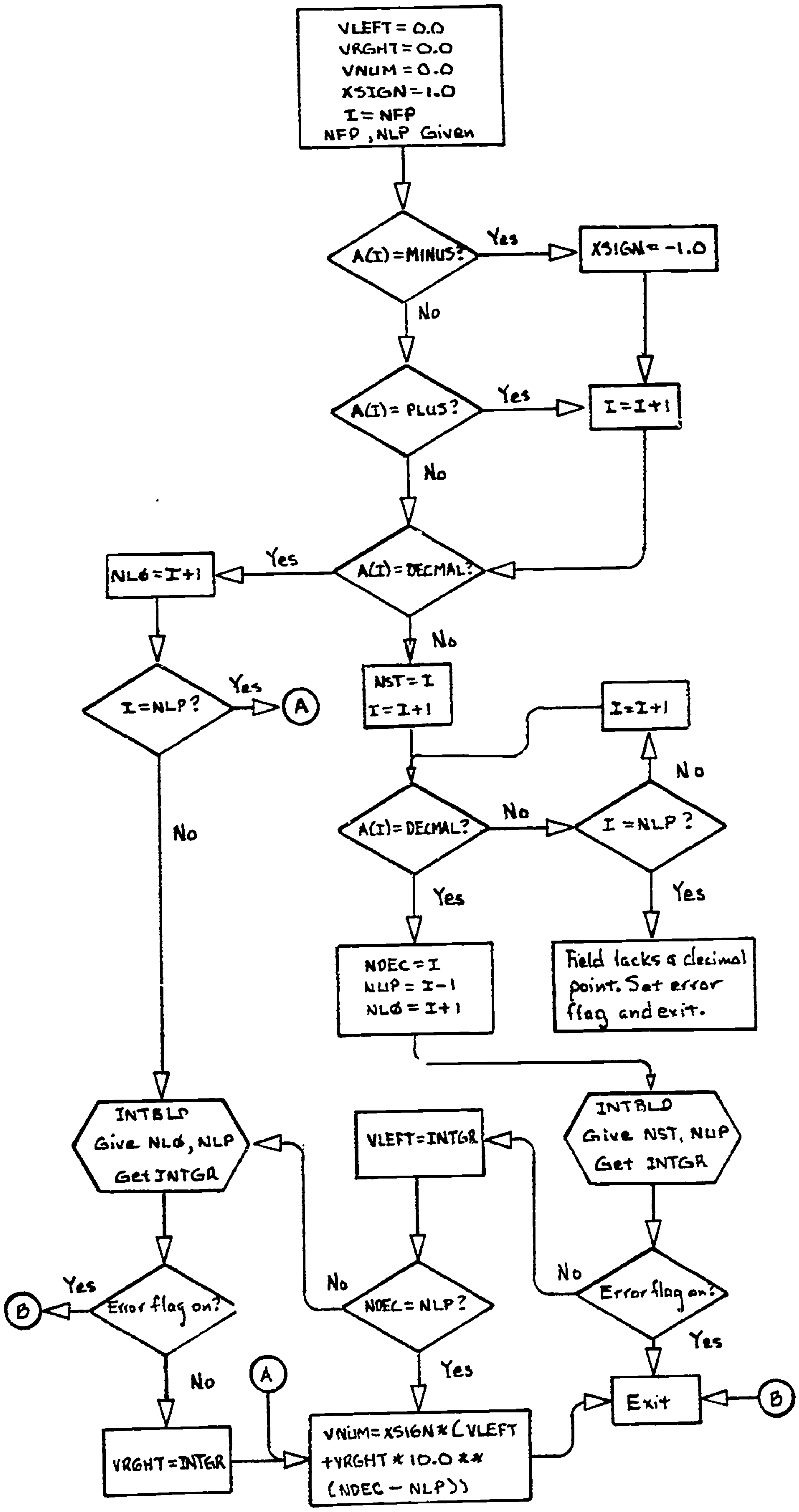
MINUS reference word containing alphanumeric minus sign

VLEFT integers to left of decimal point, converted to decimal number

VRGHT integers to right of decimal point, converted to decimal number

NFP index of first word in array A to be checked

Fig. 5 - PROCESS DECBLD



NLP index of last word in array A to be checked

NST index of first integer in character string, if first integer is to left of decimal point

NDEC index of word in character string in A containing decimal point

NUP index of word in character string preceding A (NDEC)

NLO index of word in character string following A (NDEC)

VNUM decimal number represented by character string in array A

XSIGN factor to adjust VNUM for minus

4.1 Input of Control Data, CXLTE

Most of the variables in figure 6 have been defined in 3.0 and 4.0. The additional definitions of importance are:

IERR - number of processing (input) errors detected

MAXR - limit on number of processing errors, programmer supplied

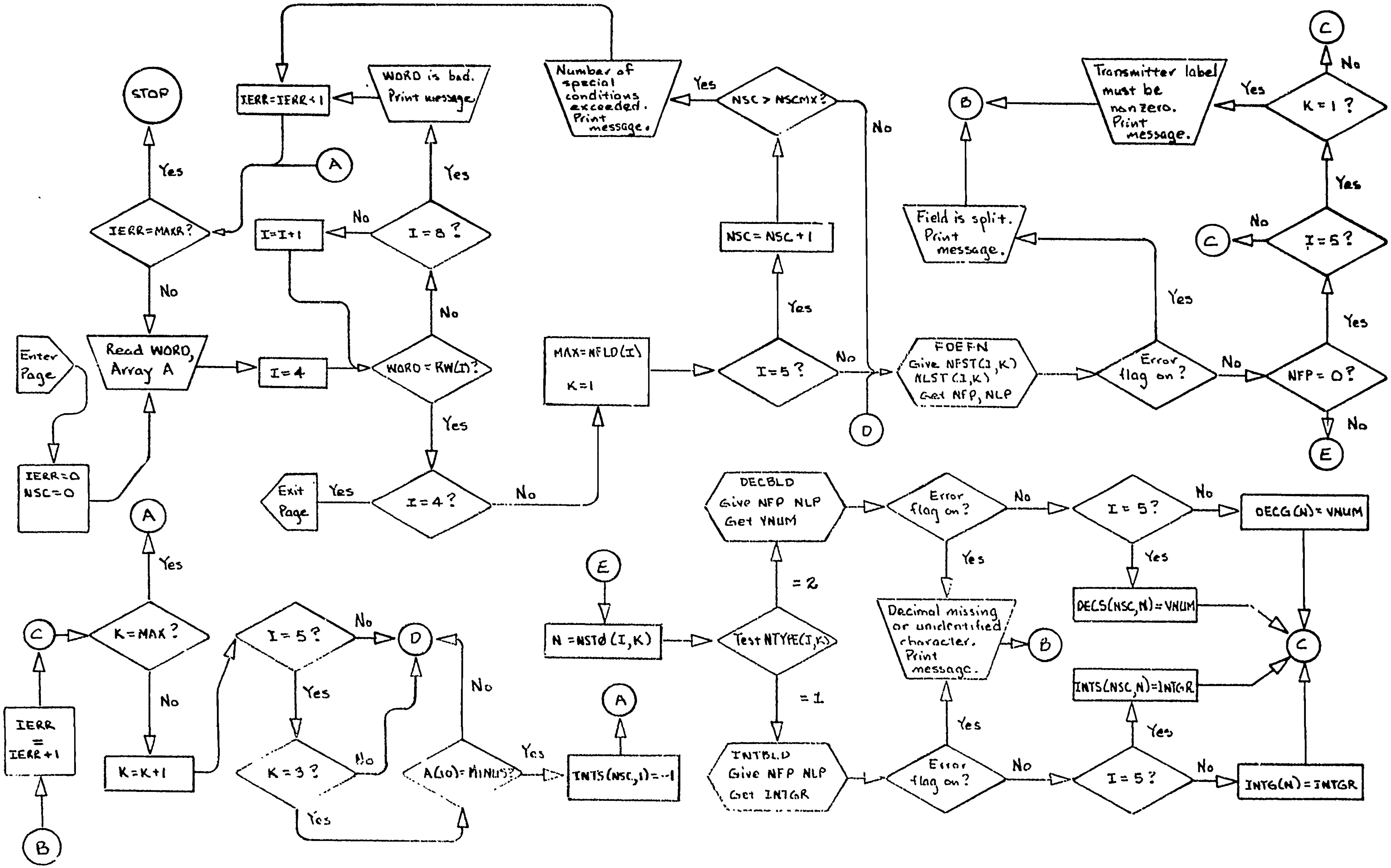
NSC - number of special control cards processed

NSCMX - limit on number of special control cards, programmer supplied.

The SC card processed by this routine is a detailed example in figure 2 and cards GC1, GC2 and GC 3 are outlined in general terms in figure 1.

In figure 6 the routine first compares the WORD with reference array RW to find the card type. If the matching index I = 4, the first antenna card has been encountered and the program exits. If I is no value from 4 through 8, WORD is misspelled or a card is in the wrong portion of the data deck.

Fig. 6 - CXLTE - INPUT ROUTINE FOR CONTROL CARDS



Branches are made at four points if I = 5 (card is SC). The first branch makes certain that the space allotted for special controls will not be exceeded. The second branch, when a field is blank, insures that it is not field one since field one in an SC card must contain the positive integer label of a transmitter. The third branch (at lower left) checks computation parameter NCOMP for a minus sign because INTBLD digest only positive integers. If NCOMP is negative, all computations for the receiver group or receiver involved will be omitted so no more fields are transformed. The fourth (actually two branches at lower right) stores transformed numbers in "special" arrays INTS and DECS.

4.2 Input of Antenna Data, AXLTE

Layout of the card type processed by this section, and the manner in which groups of cards pertaining to a particular antenna should be arranged in the deck are shown in figure 7.

New problem and local variables in figure 7 and 8 are defined below.

Definitions:

AZM - the direction, measured in degrees, in which a particular antenna gain is applicable.

GN - the antenna gain in decibels associated with AZM.

IALBL - positive integer label identifying a particular antenna and data pertaining to it.

LINKA - a parameter which, if non blank in the first data card pertaining to a receiver antenna, causes that antenna to be a candidate for selection at receiver locations having no antenna specified.

LREF - antenna label on the data card previously processed.

MNANT - maximum number of antennas allowed in the program (programmer supplied).

NANT - number of antennas in the current analysis.

NEW - a switch that is 1 if data card involves a new antenna, 0 otherwise.

NLOOP - a local variable, one less than the number of AZM-GN pairs on a data card, used to control processing in AXLTE.

NP - the number of AZM-GN pairs for a given polarization of a given antenna.

NPMAX - maximum number of pairs NP per polarization per antenna allowed in the program (programmer supplied).

NPNT - number of the pair to be processed next for the current antenna and polarization.

NPOL - polarization on the data card previously processed (1 - primary, 2 - cross).

Referring to figure 7 each data card must contain the antenna's identifying lable and the polarization to which the data applies. The card may also contain a nonblank linking parameter and from one to five direction-gain pairs describing the antenna's performance. The number of pairs on the cards is placed in column 72.

The program anticipates that transmitter antennas will frequently by omnidirectional. These antennas (number 53 in figure 7) can be described with one pair, primary polarization. The program also anticipates that receiver antennas will most frequently be directional, so tables for the two polarizations of a receiver antenna must contain at least two pairs each to permit inter-

Fig. 7 - CARD LAYOUT AND SECTION OF DECK - ANTENNA DATA

		2	4 5	7	9 13	15 19		57 67	68	Position in A (NFST, NLST)
Abbb		Linking Word LINKA	Antenna Label IALBL	Polarization NPOL	Direction AZM in Degrees	Gain GN in Decibels	. . . .	Fifth AZM-GN Pair Position	Number of Pairs on Card	Variable Name
					1	2				Field
		6	8 9	11	13 17	19 23		61 71	72	Card Column

	LINKA	IALBL	NPOL	PAIR 1		PAIR 2		PAIR 3		PAIR 4		PAIR 5		PAIRS ON CARD
A		53	1	0.	18.									1
A	1	14	1	0.	12.	30.	7.	60.	0.	90.	-8.	120.	-4.	5
A		14	1	150.	-4.	180.	-6.	210.	-4.	240.	-4.	270.	-8.	5
A		14	1	300.	0.	330.	7.	360.	12.					3
A		14	2	0.	-7.	45.	-7.	90.	-15.	135.	-15.	180.	-20.	5
A		14	2	225.	-15.	270.	-15.	315.	-7.	360.	-7.			4
A		27	1	0.	14.	60.	8.	120.	8.	180.	14.	240.	8.	5

polation. The directions in data for any antenna must be presented in ascending order, but the increment between directions need not be uniform. In any table with more than one point the first direction must be 0 degrees and the last, 360 degrees.

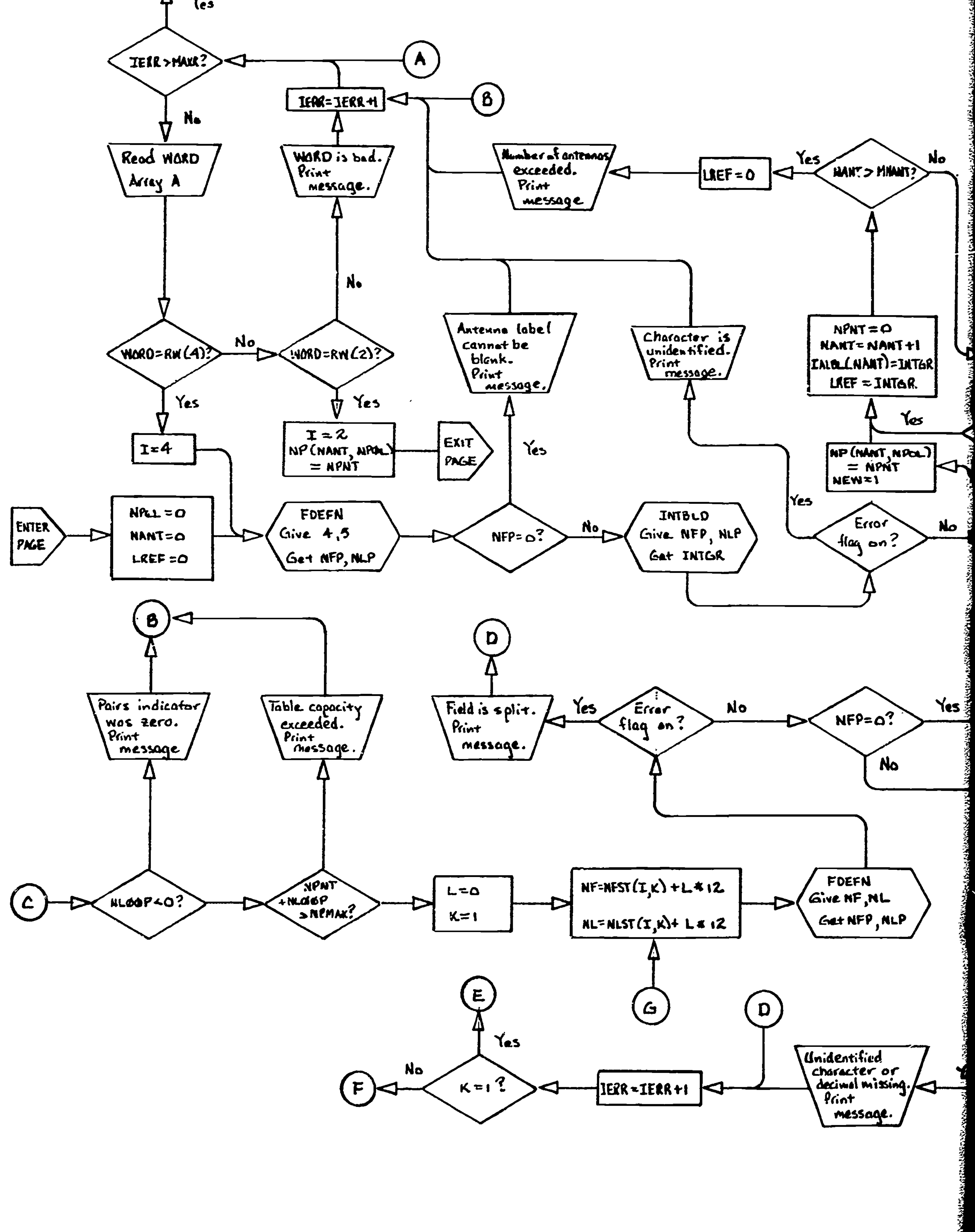
To calculate interference effects from cochannel signals of opposite polarization, a receiver antenna must have a cross-polarization gain table (NPOL = 2) in addition to the gain table for its primary polarization (NPOL = 1). For a given antenna these two tables must be adjacent in the data (number !4 in fig. 7).

During execution the program will select an antenna to be used at a receiver for which no antenna is specified, using as the criterion RSNRAT (defined in 3.0). If a receiver antenna is to be a candidate for this selection process, a character is placed in LINKA of the first data card in the deck involving the antenna (number !4 in figure 7).The selection process itself is explained in 5.1 and 6.3 .

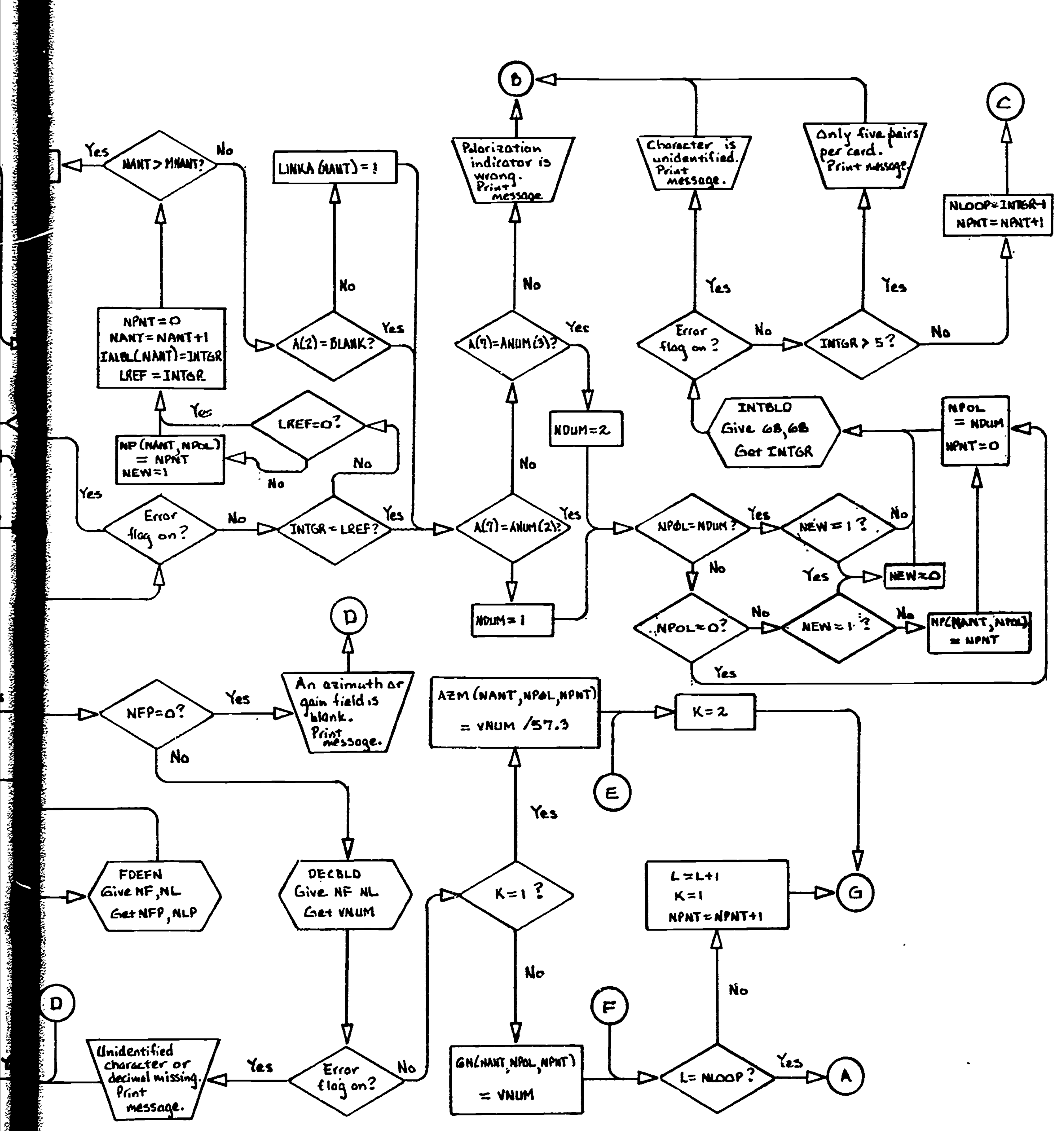
The two fields on the A card defined by NFST and NLST for AXLTE (described below) are the direction and gain fields of the first pair on the card.

Figure 8 shows the suggested input routine AXLTE for A cards. Error messages are largely self-explanatory and will not be included in the description. The antenna label is translated first. If it differs from the label on the previous card, the previous table is closed by recording NP (NANT, NPOL), a new table is opened, and LINKA is set equal to 1 if nonblank so the antenna can be ordered(5.1). If it does not differ, the routine proceeds immediately to polarization.

Fig. 8 - AXLTE - INPUT ROUTINE FOR AN



PUT ROUTINE FOR ANTENNA CARDS



Polarization is translated next. The group of decision points at the right of figure 8 near the center closes a table and opens another when the polarization changes but the antenna label remains the same.

The loop parameter NLOOP, pair to be processed NPNT, field offset parameter L and field index K are initialized next. Then the routine translates and stores all pairs on the card, offsetting by multiple L of 12 (the distance between starting columns of adjacent pairs) from the first pair. The first pair are fields 1 and 2; their starting and ending positions are stored in reference arrays NFST and NLST. Directions are converted to radians. When the first X card is encouuntered the program exists from AXLTE.

4.3 Input of Transmitter Data, XXLTE

Figure 9 shows the card types that contain transmitter data, along with a sample section of the data deck. Additional problem and local variables of significance in figures 9 and 10 are defined below.

Definitions:

H - word containing alphanumeric character H

IAXLBL - positive integer label identifying the antenna type used to broadcast frequencies at the transmitting location.

IPOL - index of position in array A containing polarization indicator.

Fig. 9 - CARD LAYOUTS AND SECTION OF DECK - TRANSMITTER DATA

Xbbb	Transmitter Label IXLBL	X Coordinate XT	Y-Coordinate YT	Elevation NXEL	Antenna Azimuth TAZM	Transmitter Antenna Label IAXLBL	Line Loss TLLSS	Broadcast Frequency ITXFR	Polarization NXPOL	Broadcast Power XPWR	Antenna Height IXHGT	Variable Name
	1 3	5 10	12 17	19 23	25 29	31 32	34 38	40 43	45	46 50	52 55	Position in A (NFST, NLST)
	1	2	3	4	5	6	7	8		9	10	Field
	5 7	9 14	16 21	23 27	29 33	35 36	38 42	44 47	49	50 54	56 59	Card Column

XFRb	ITXFR	NXPOL	XPWR	IXHGT	• • • •	Fourth Set of Frequency Characteristics		Variable Name
	1 4	6	7 11	13 16		52 67	68	Position in A
	5 8	10	11 15	17 20		56 71	72	Card Column

	IXLBL	XT	YT	NXEL	TAZM	IAXLBL	TLLSS	ITXFR	NXPOL	XPWR	IXHGT	
X	101	3.7	5.6	703		53	1.	2503	H	10.	75	
X	203	6.4	11.1	800		53	1.					
XFR	2563	H 10.	90	2575	V		100					2
X	104	4.1	6.6	750	15.2	27	1.	2629	H			

ITXFR - a frequency broadcast at transmitting location, megacycles.

IXHGT - height of the antenna used to broadcast a frequency, feet.

IXLBL - positive integer label identifying the transmitting location.

KFACT - an offset factor that is nonzero in processing fields on XFR cards.

KHGHT - value of last antenna height stored, feet.

MNXM - maximum number of transmitting locations permitted (programmer supplied).

NFR - index of frequency being processed for transmitting location.

NFRQ - total number of frequencies broadcast from transmitting location.

NLOOP - loop parameter that is nonzero when sets of frequency characteristics are being processed on XFR card, zero otherwise.

NXEL - elevation of the transmitting location, feet.

NXM - number of transmitting locations in the current analysis

NXPOL - polarization of a broadcast frequency (H-horizontal, V-Vertical)

PWR - value of last transmitter power stored, watts.

TAZM - direction of 0 line of antennas at transmitting location, degrees.

TLLSS - line loss applied for frequencies at transmitting location, decibels

V - word containing alphanumeric character V.

XPWR - transmitter power for a frequency, watts.

XT - X coordinate of transmitting location, miles.

YT - Y coordinate of transmitting location, miles.

The X card contains data locating a transmitting site by position and elevation and specifying one type and orientation for antennas in use at the site. This feature presupposes that the majority of antennas in a network will be omnidirectional and have the same gain. Each different antenna and/or orientation employed at a site requires a different X card (with duplicate position and elevation).

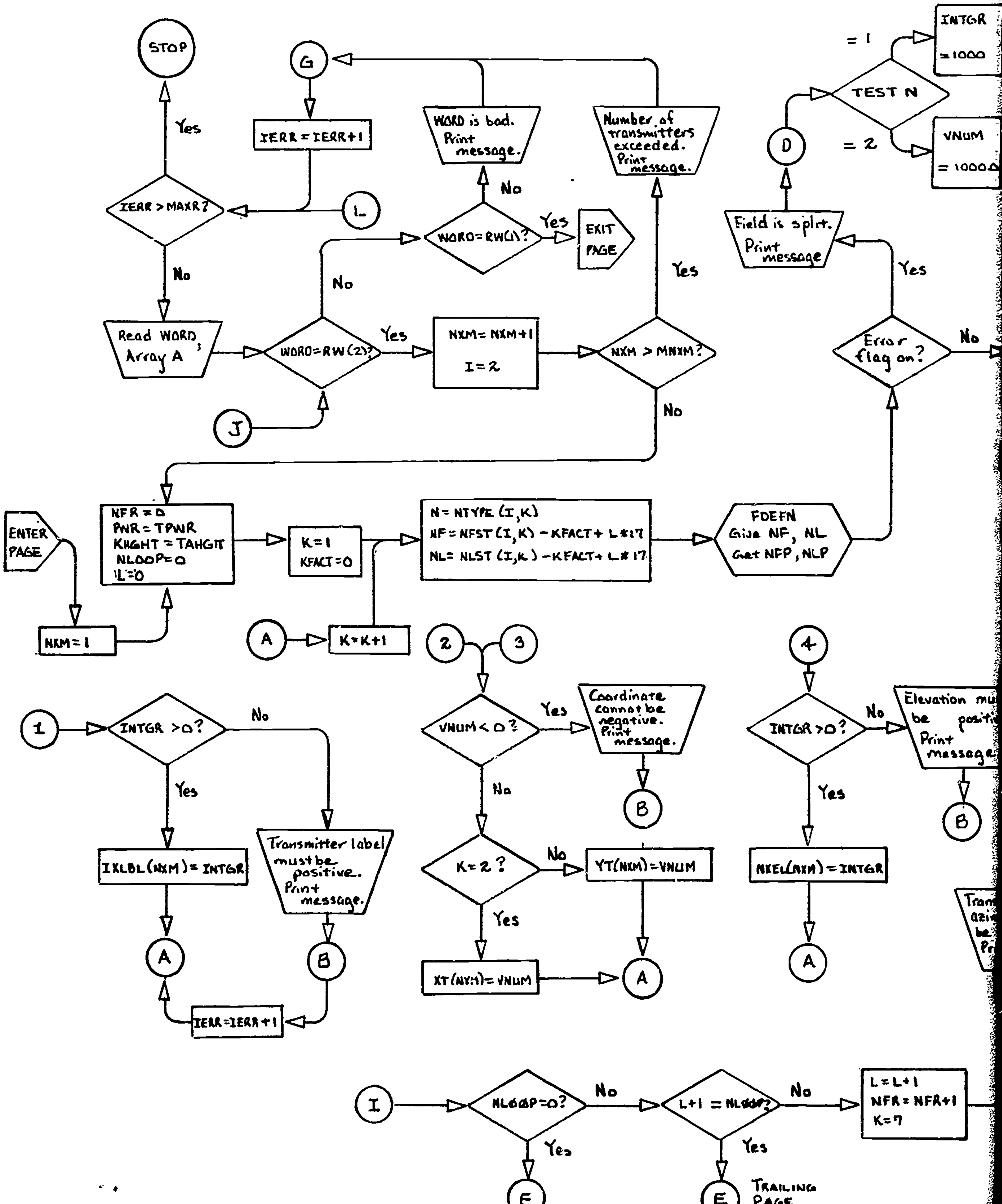
If only one frequency is broadcast using a given antenna and orientation, its value, polarization, broadcast power and antenna height are placed on the X card. When more than one frequency is broadcast, these fields on the X card are left blank, and characteristics for the several frequencies are placed on XFR cards trailing the X card to which they apply (transmitting location 203 in figure 9). The number of sets of four characteristics is placed in column 72 of the XFR card.

The blank XPWR field in the XFR card for location 203 causes routine TXLTE to insert as frequency broadcast power the last nonzero broadcast power PWR processed for the location, in this case 10 watts (for frequency 2563 on the same card). The same rule applies to blank IXHGT fields. When the first XPWR and IXHGT fields encountered are blank (location 104 in figure 9) the values TPWR and TAHGT, respectively (see 3.0) are stored.

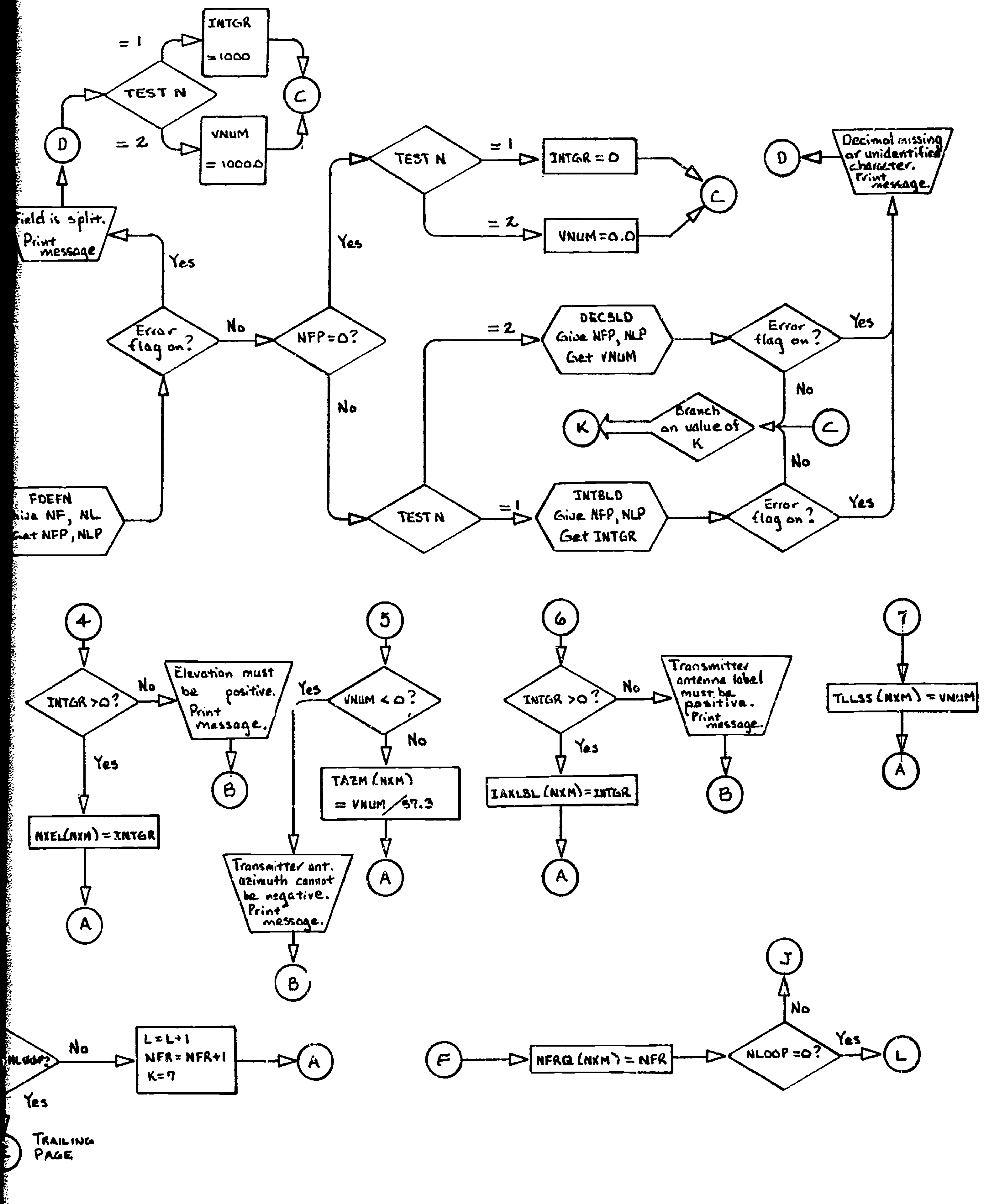
Routine XXLTE for processing X and XFR cards is shown in figure 10 & 10a(trailer). The routine processes X cards with field index K starting at 1 and KFACT set to 0. Each field is translated according to position (NFST and NLST) and type (N = NTYPE), then stored by branching on K to that portion of the routine that checks and stores the particular field being processed.

When field 8 is translated (trailing page) a check is made on NLOOP to determine which card type is being processed. If NLOOP and field 8 are both zero, an X card is in process and one or more XFR cards with sets of frequency characteristics follow. In this case the routine immediately reads the next card(secondary read statement) and processes its sets using offset factor KFACT and multiple L of 17 (the distance between set starting positions on the XFR card). If NLOOP is zero and field 8 nonzero, all information is contained on the X card; the routine continues checking and storing through field 10 of the X card and returns to its primary read statement (point L). If NLOOP is nonzero, the routine processes the sets (fields 8, 9 and 10, offset) on the XFR card, then returns to the secondary read statement (point E, trailing page). If another XFR card follows, it will be processed. Otherwise the routine closes the frequency table for the current location (at point F) and goes on to identify the card just read (point J).

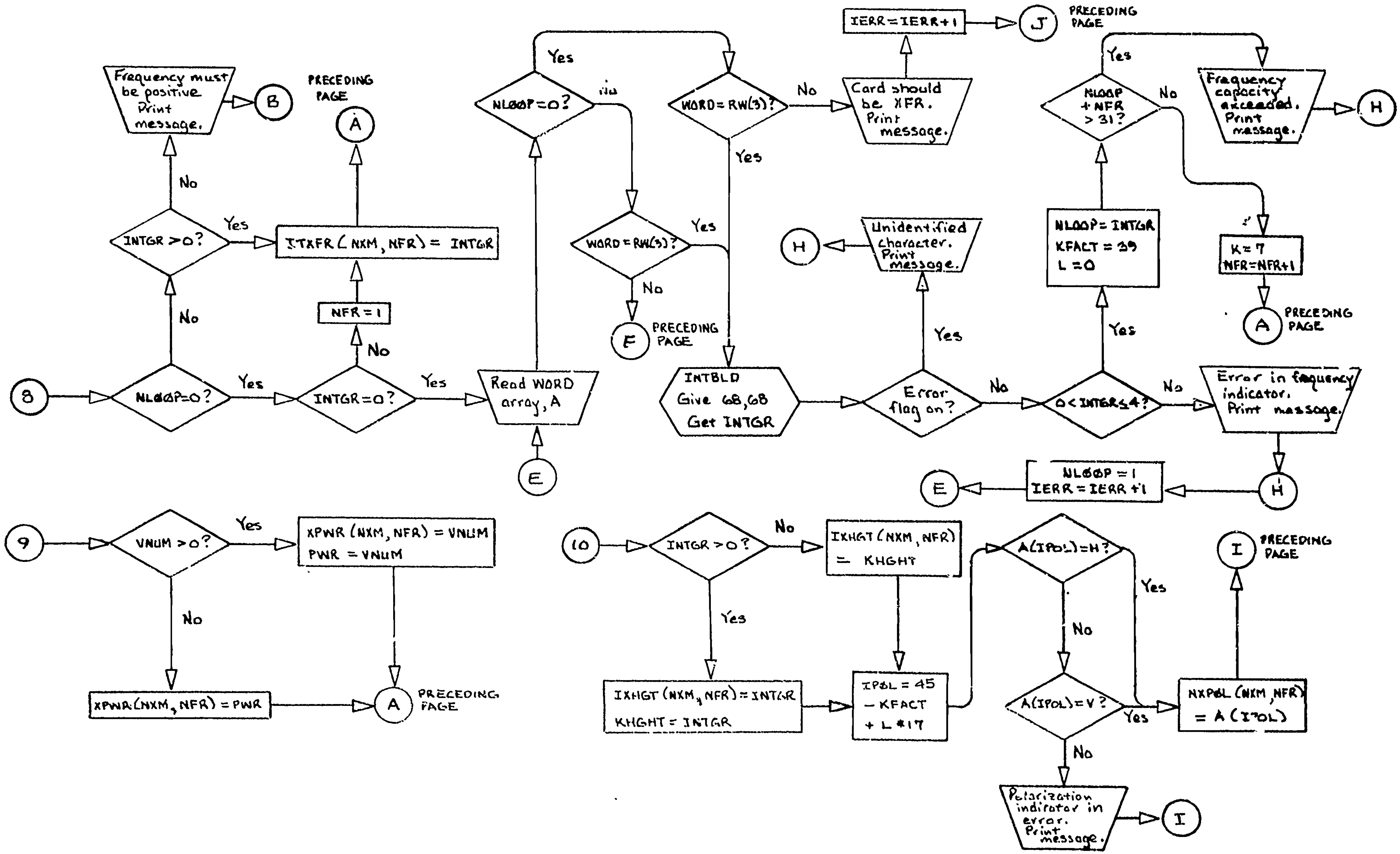
Fig. 10 - XXLTE - INPUT ROUTINE FOR TRA



– INPUT ROUTINE FOR TRANSMITTER CARDS



XXLTE - BRANCHES FOR K= 8,9,10



4.4 Input of Receiver Data, RXLTE

The characteristics of each receiver are described on the R card, shown in figure 11. Problem and local variables from figures 11 and 12 are defined below.

Definitions:

- IARLBL - positive integer label identifying the antenna used at the receiver.
- IRFR - receiver frequency, megacycles.
- IRHGT - receiver antenna height, feet.
- IRLBL - positive integer label identifying the receiver
- IRXL - positive integer label identifying the transmitter which serves or owns the receiver.
- MNRC - maximum number of receivers allowed in the program.
- NRC - number of receivers in the current analysis
- NREL - receiver elevation, feet
- NRPOL - receiver antenna polarization (H - horizontal, V - vertical)
- RAZM - bearing from local north of 0^{o} line of the receiver antenna, degrees
- RLLSS - line loss at the receiver, decibels
- RNS - noise figure at the receiver, decibels
- XR - receiver X coordinate, miles
- YR - receiver Y coordinate, miles

Figure 12 is relatively straight forward. It shows RXLTE, which translates receiver information from R cards. The R card contains data locating a receiver by position and elevation. Much of the other data is optional; alternate sources in later routines for data not furnished on the input R card are explained in the

following paragraphs.

The transmitter label IRXL identifies the source transmitting location for the received signal. If the field is blank, the program selects as a source for the received signal the closest transmitting location. If no transmitting location defined by an X card contains a label matching IRXL, the program creates a dummy location at which to group any receivers with the unrecognized label. Only interference effects can be computed for these receivers, and few of the other fields on their R cards may be left blank. Mechanics of these operations involving IRXL are explained in 5.3.

Fig. 11 - CARD LAYOUT - RECEIVER DATA

	1 3	5 7	9 14	16 21	23 27	29 30	32 36	38 42	44 47	49	51 55	57 60	Position in A(NFST, NLST)
Rbbb	Receiver's Transmitter Label IRXL	Receiver Label IRLBL	Receiver X Coordinate XR	Receiver Y Coordinate YR	Elevation NREL	Receiver Antenna Label IARLBL	Antenna Azimuth RAZM	Line Loss RLLSS	Receiver Frequency IRFR	Polarization NRPOL	Receiver Noise RNS	Antenna Height, IRHGT	Variable Name
	1	2	3	4	5	6	7	8	9	10	11	12	Field
	5 7	9 11	13 18	20 25	27 31	33 34	36 40	42 46	48 51	53	55 59	61 64	Card Columns

The receiver label IRLBL is ordinarily included for the analyst's convenience in inspecting computer output. However, both IRXL and IRLBL must be present to address special controls (an SC card, see 4.1) to the receiver.

If the receiver antenna label field IARLBL is blank, an antenna will be selected by computation and comparison in electronic computations involving the receiver (see 6.3). If electronic com-

putations have not been specified for the receiver, this blank field is probably an error. In the event interference computations are begun for the receiver without an antenna's having been selected, one is assigned arbitrarily as noted in 6.7.

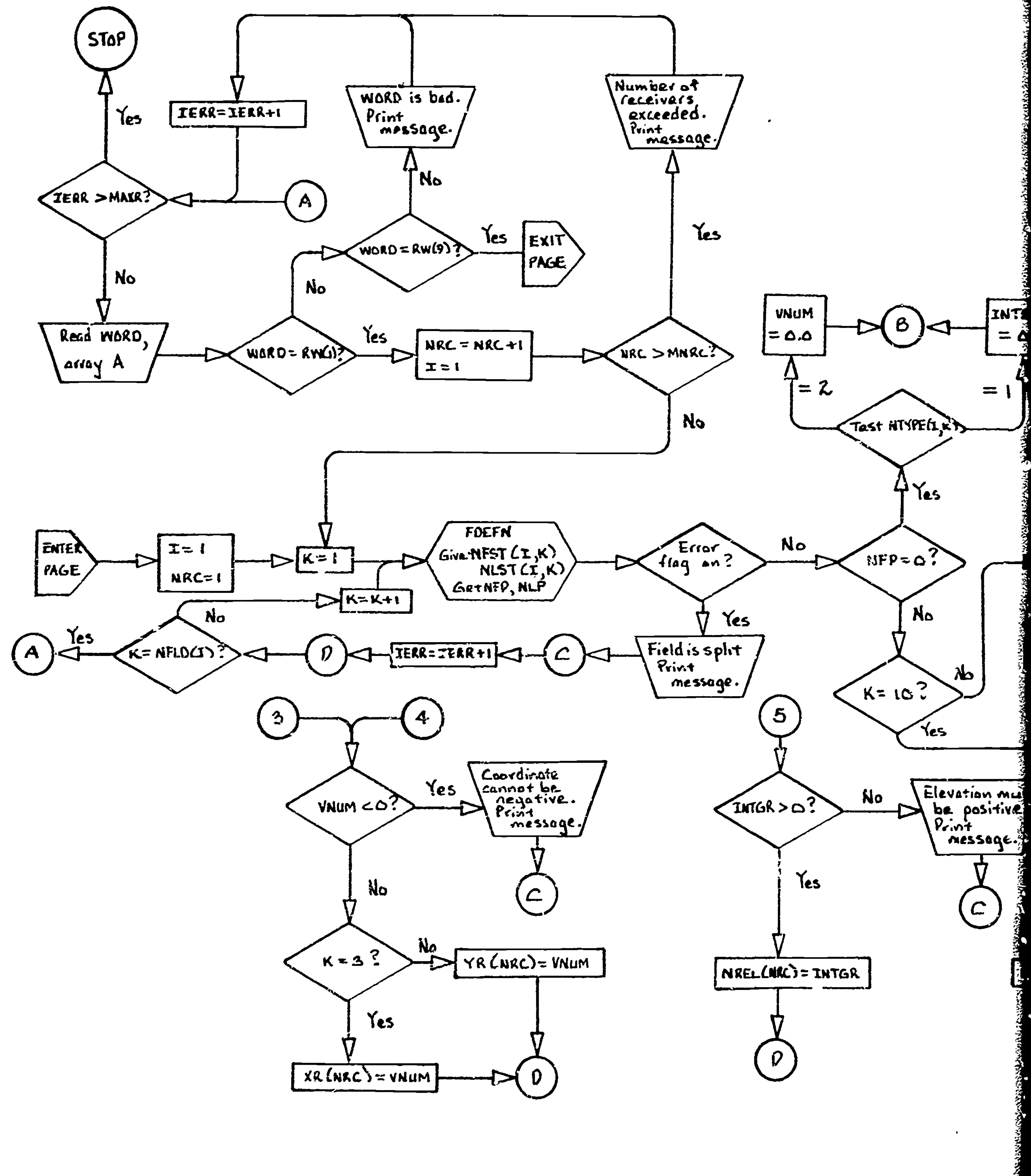
A blank azimuth field RAZM causes the program to assume that the receiver antenna centerline lies along the line-of-sight to its source transmitting location. RAZM is then computed based on the source location's coordinates (see 6.3 and 6.7). If the source is a dummy, this field cannot be blank.

When the receiver frequency field IRFR is blank, the program selects at random a frequency (and its associated polarization) that is broadcast from the receiver's source transmitting location (see 5.3).Again, this option can only be exercised if the transmitting location is not a dummy.

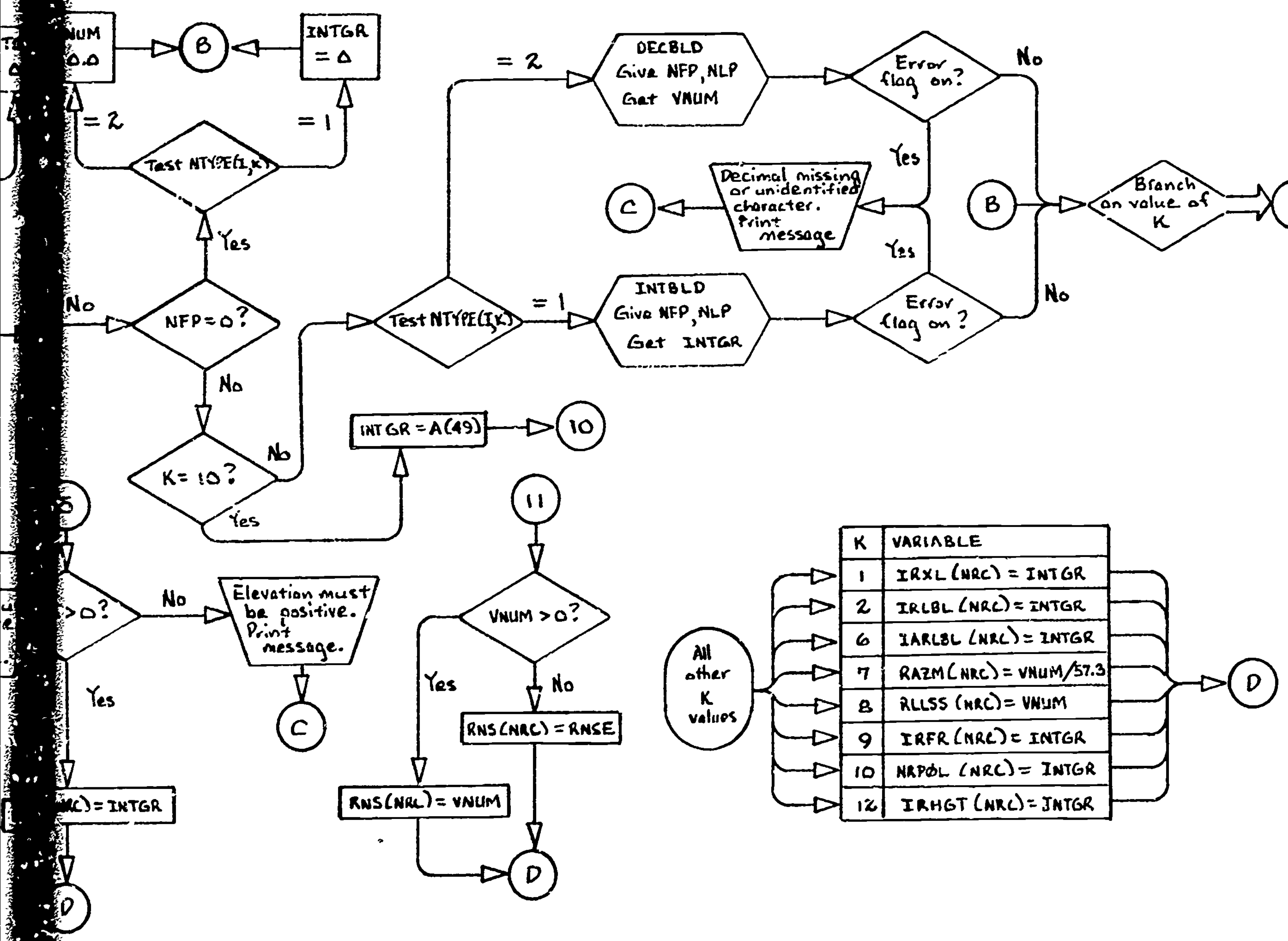
The IRHGT field is for existing or assumed antenna heights. If the field is blank, a value for antenna height is stored when the program exits from topography computations following electronic computations (figure 50). The value stored at that point is the antenna height necessary to provide Fresnel zone clearance (the constant FZCL, see 3.0) for the signal path at the worst obstacle in the terrain record.

The RNS field is the noise figure for the receiver. A blank field results in storage of reference value RNSE (see 3.0).

Fig. 12 - RXLTE - INPUT



2 - RXLTE - INPUT ROUTINE FOR RECEIVER CARDS



5.0 Precomputation Processes

If IERR is non zero after the data deck has been processed, an exit should be made from the program to correct input errors. Otherwise several ordering, checking and linking functions are performed before computation begins, and files of reference data may be read.

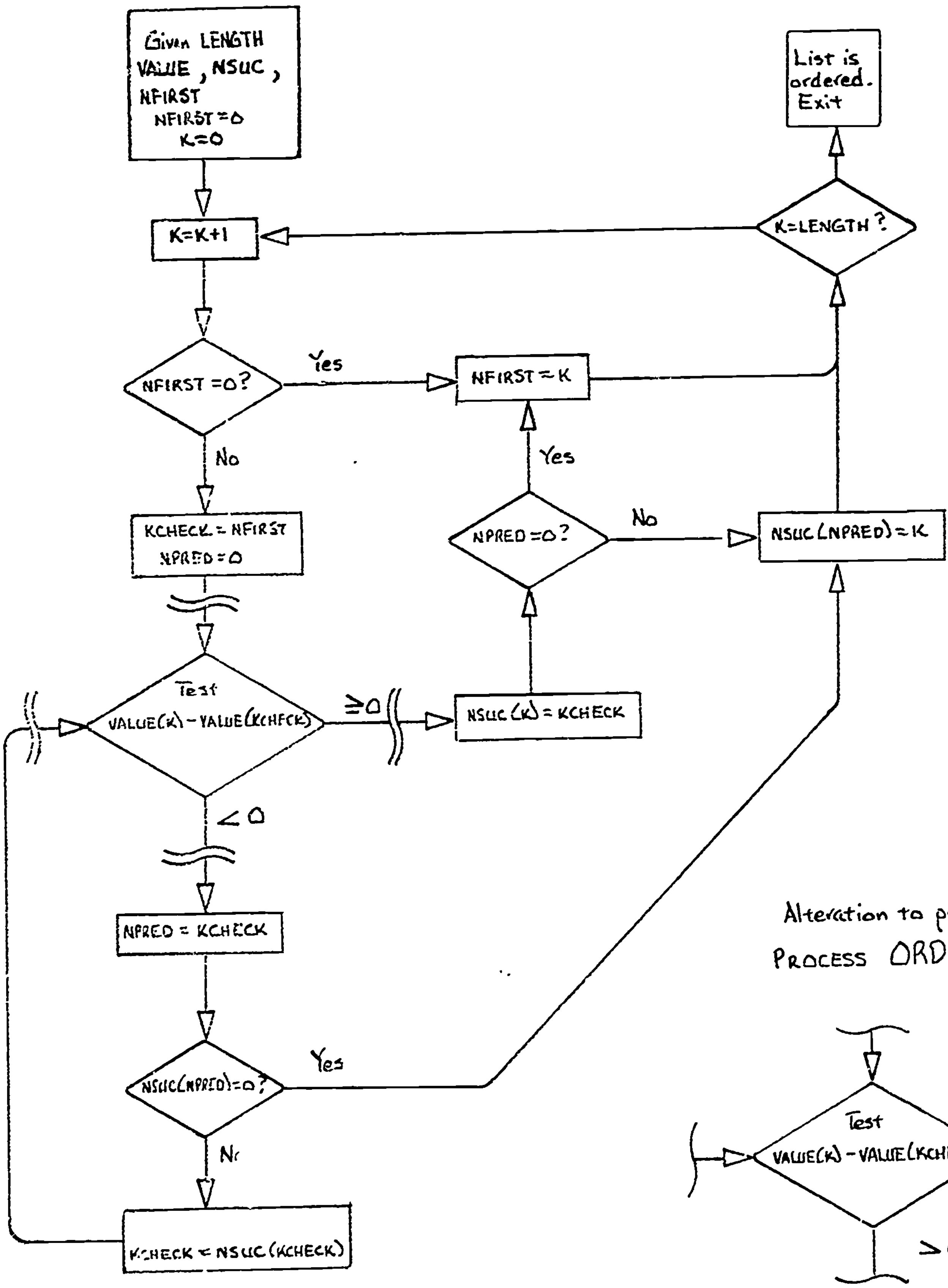
5.0.1 Ordering Processes ORDERH and ORDERL

At several points in the program it is convenient to order data. The ordering processes used are shown in figure 13. The variables involved are defined below. ORDERH orders a list with highest values first. ORDERL orders a list with highest values first.

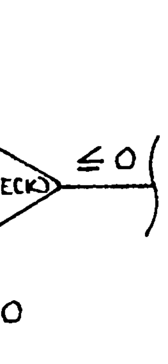
LENGTH	length of the list to be ordered
K	index of value currently being ordered
Value (k)	the Kth number in the list being ordered
NSUC (k)	index of value succeeding VALUE (k) in the ordered list
NFIRST	index of the highest (lowest) value in the ordered list
NPRED	index whose value was just previously compared with VALUE (k)
KCHECK	index whose value is currently being compared with VALUE (k)

These processes require as inputs the LENGTH of the list to be processed, the variable NFIRST in which the index of the leading ordered value is to be stored, a single-subscripted array NSUC showing the successor to each list member, and the

Fig. 13 - PROCESS ORDERH



Alteration to produce
PROCESS ORDERL



list VALUE to be ordered. Note that these processes can order lists with several subscripts if only one subscript varies in the ordering process (i.e., other subscripts are constant). Examples of processed lists are shown in figure 14.

5.0.2 Search Techniques

One reason for ordering lists or arrays in this program is to make the program more efficient by speeding up the search for obstacles and interferring transmitters relative to each receiver. Complete computations are done only for obstacles and transmitters within certain distances of the receiver. Ordering combined with other schemes permits prompt location of the list sections whose members may fall within these distances. The means of preparing the lists to be searched after they are ordered are explained below. Other elements of the search techniques are discussed later.

Assume that a list of NTOT members is divided into NSECT approximately equal sections, and that it can be determined whether or not a value for which we are searching lies within a particular section by testing the section's first member. Then the probable number of searches to find the correct value is half the number of sections plus half the length of a section, or

Probable Number P = NSECT/2 + (NTOT/NSECT) /2

This number P is a minimum when

$$NSECT = \sqrt{NTOT}$$

For programming ease we would like the number of sections into which the list is divided to be a power of 2.

Fig. 14 - EXAMPLES OF ORDERED LISTS

LENGTH = 6

NFIRST: 0

List before processing

INDEX K	VALUE (K)	NSUC (K)
1	16.0	0
2	3.0	0
3	5.0	0
4	29.0	0
5	5.0	0
6	8.0	0

NFIRST: 4

List processed by ORDERH

INDEX K	VALUE (K)	NSUC(K)
1	16.0	6
2	3.0	0
3	5.0	2
4	29.0	1
5	5.0	3
6	8.0	5

NFIRST: 2

List processed by ORDERL

INDEX K	VALUE (K)	NSUC (K)
1	16.0	4
2	3.0	5
3	5.0	6
4	29.0	0
5	5.0	3
6	8.0	1

Intuitively there exists an integer in such that

$$2^K = \sqrt{NTOT} < 2^L$$

$$L = K + 1$$

and one of these is the best power of 2 to pick. Comparing probable numbers P for the two candidates shows that K is best when

$$NTOT < 2^K \times 2^L$$

If the above inequality is not true, L is best.

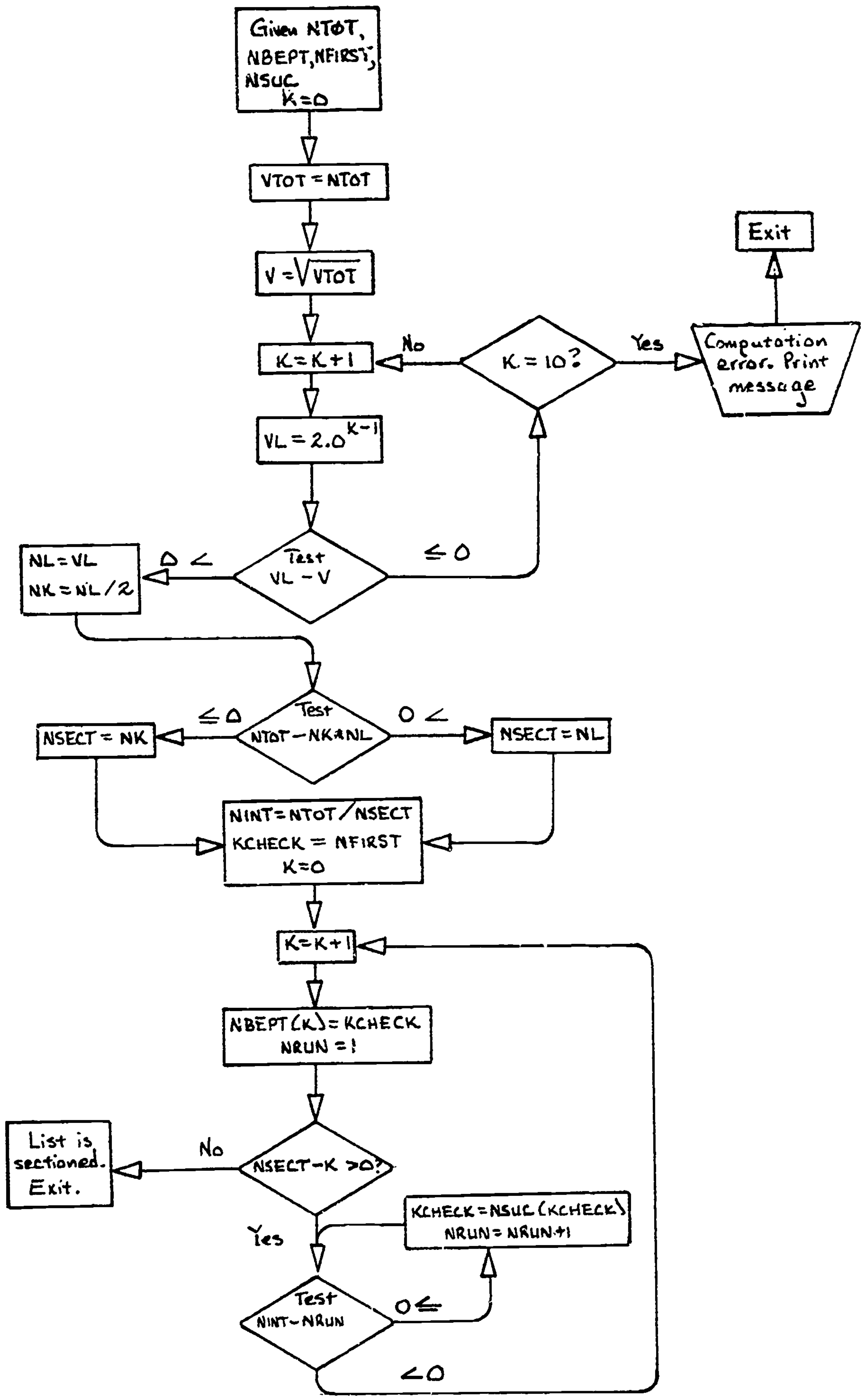
Process SECTN divides an ordered list as outlined above (figure 15

Definitions of the variables used are:

NTOT	number of members in list
VTOT	decimal equivalent of NTOT
V	square root of VTOT
VL	smallest power of 2 greater than V
VK	largest power of 2 less than or equal to V
NL	integer equivalent of VL
NK	integer equivalent of VK
NSECT	number of sections into which list should be divided
NINT	number of members in each section
NFIRST	leading member in list
NBEPT	array of list members heading the NSECT sections
NSUC	successor to each list member
KCHECK, NRUN	dummy variables

Note that due to roundoff in computing NINT there may be extra members in the last section of the list. In large lists the discrepancy can be substantial. A more sophisticated scheme can be concocted if desired which reduces this discrepancy by considering the magnitude of the roundoff that occurred.

Fig. 15 - PROCESS SECTN



5.1 Order and Check the Antenna Data

Figure 16 shows the processing necessary on antenna data prior to computations. Process ORDERL is applied to all antennas with LINKA = 1. This last condition necessitates the changes to ORDERL shown in the upper right portion of the figure. The changes insure that:

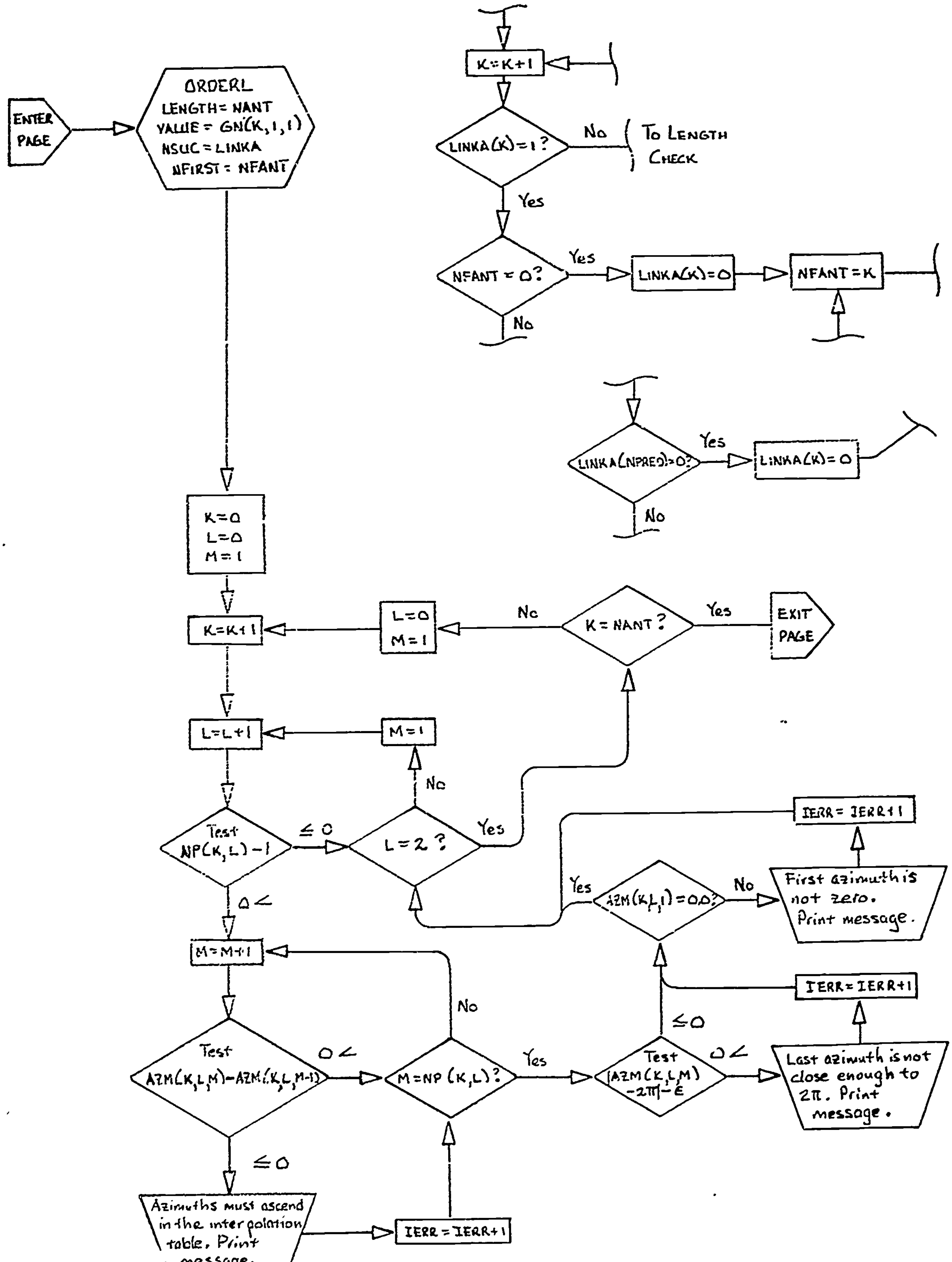
1. only antennas with LINK = 1 are ordered,
2. the first antenna ordered has no false successor, and
3. any antenna placed last in the ordered list has no false successor.

Note that the value by which the antennas are ordered is the gain on the antenna centerline, primary polarization. As explained in 6.3 the program chooses, for receivers with no antenna specified, the smallest such gain (and thus the antenna to which it applies) permitting satisfaction of the RSNRAT criterion.

The remainder of figure 16 consists of a check to make sure the azimuths in each antenna table begin at 0, are strictly monotonic increasing, and end sufficiently close to 2π The two additional variables that appear in fig. 16 are

LINKA -	index of successor to a member of the ordered antenna list
NFANT	first antenna in the ordered list

Fig. 16 - ORDER AND CHECK ANTENNA DATA

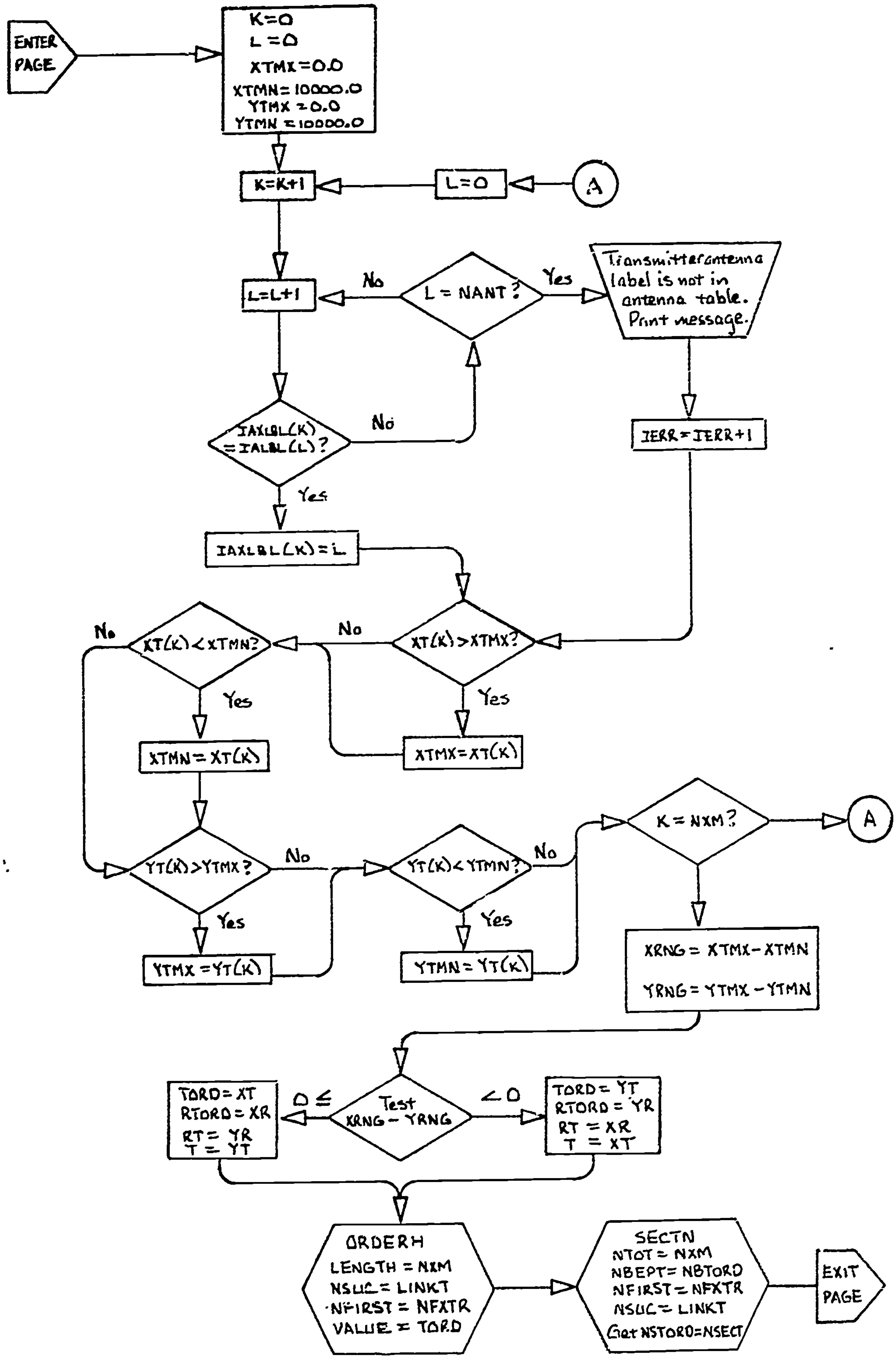


5.2 Link and Order Transmitter Data

Figure 17 depicts precomputation processing of transmitter data. For each transmitter the antenna table is searched and the index L of the antenna stored in transmitter attribute IAXLBL in place of the antenna label. In addition the transmitter's coordinates, XT and YT, are tested against (and may supercede) the maximum and minimum so far encountered for each coordinate. When these two tasks have been completed for all transmitters, ranges XRNG and YRNG between the coordinate maximums and minimums are calculated. The list of transmitters is ordered on the coordinate the range of which is larger, then divided into sections.

The rationale behind ordering is indicated in figure 18 . Only transmitters X within distance D (equal to DISTO defined in 3.0) of receiver R are considered in calculating interference effects on R. Ordering the list on a coordinate enable the program to recognize (by checking transmitter - receiver distance with respect to that coordinate alone) that up to one point in the list, and after a second point, transmitting locations are not within the required distance. After the second point is reached, testing for interference calculations can stop. Ordering on the coordinate with maximum range means (assuming a fairly uniform geographic distribution of transmitting locations within the rectangle defined by the ranges) that fewer locations will fall within that portion of the list where the actual distance between transmitting location and receiver must be computed in deciding on whether or not to do interference calculations.

Fig. 17 - LINK AND ORDER TRANSMITTER DATA

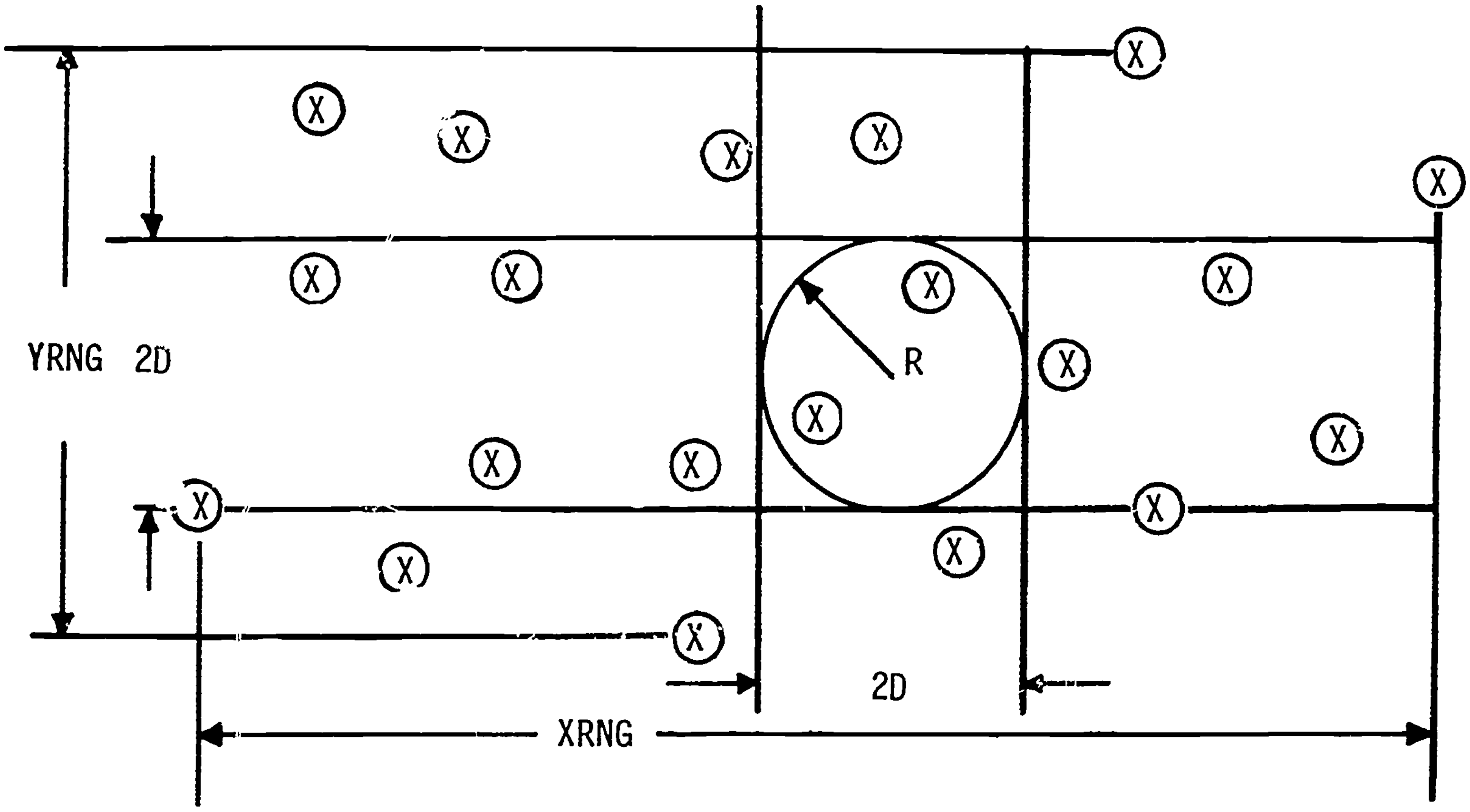


How the computations use results of ORDERH and SECTN to advantage is illustrated in 7.3. Note that by setting D arbitrarily large, interference effects will be calculated for all transmitting locations Pertinent variables from figure 17 are defined below.

Definitions:

LINKT -	index of successor to a member of the ordered transmitting location list
NBTORD -	array of members heading the NSTORD sections of the ordered list
NFXTR -	first transmitting location in the ordered list
NSTORD -	number of sections into which the ordered list is divided
RT -	receiver array corresponding to coordinate not used in ordering transmitters
RTORD -	receiver array corresponding to coordinate used in ordering transmitters.
T -	transmitter coordinate array not used in ordering transmitters
TORD -	transmitter coordinate array used in ordering transmitters
XRNG -	difference between maximum and minimum XT's found in transmitter list
XTMN -	minimum XT found in transmitter data
XTMX -	maximum XT found in transmitter data
YRNG -	difference between maximum and minimum YT's found in transmitter list
YTMN -	minimum YT found in transmitter data
YTMX -	maximum YT found in transmitter data

Fig. 18 REASON FOR ORDERING ON DIMENSION WITH WIDEST RANGE INTERFERING TRANSMITTER COMPUTATIONS



4 Eligible transmitters based on X dimension check

10 Elibible transmitters based on Y dimension check

5.3 Link and Check Receiver Data

Receiver data undergoes substantial processing before computations begin. New problem variables and pertinent local variables from figure 19, which depicts this processing, are defined below.

D - distance from receiver of transmitter currently judged closest to it

DIFF - distance between receiver I and transmitter K with respect to ordering coordinate for the transmitter list

DUM - distance between receiver I and transmitter K

IND - index of transmitter currently judged closest to receiver

IX index of transmitter owning receiver I

LINKR - index of successor to a receiver in unordered receiver group owned by transmitter

NRFR index of transmitting location broadcast frequency that matches receiver frequency

NRFST - first receiver in a transmitter's unordered group

NRLST - last receiver in a transmitter's unordered group

NUM - index of frequency randomly selected at owning transmitter and assigned to receiver

RNUM - a random number greater than zero and less than one

Referring to figure 19, if the receiver's transmitter label IRXL is zero, the program finds the nearest transmitting location and stores the negative of its index IND in the label position (lower left portion of the figure). When the label is nonzero, a search is made for a matching label IXLBL among the transmitters. In the event of a match the index K of the transmitter is stored in the receiver's label position.

Failure to find a match means that no X card with label matching IRXL was included in the data. The program then creates a dummy transmitter, marking the fact by making XT negative; and proceeds to a series of checks required for receivers belonging to such transmitters. The same series of checks must be made if the transmitter for which IRXL matches IXLBL is found to be a dummy. Such receivers must have nonzero antenna type, azimuth, frequency and polarization since no reference information (from an X card) is available to allow specification of these charac-

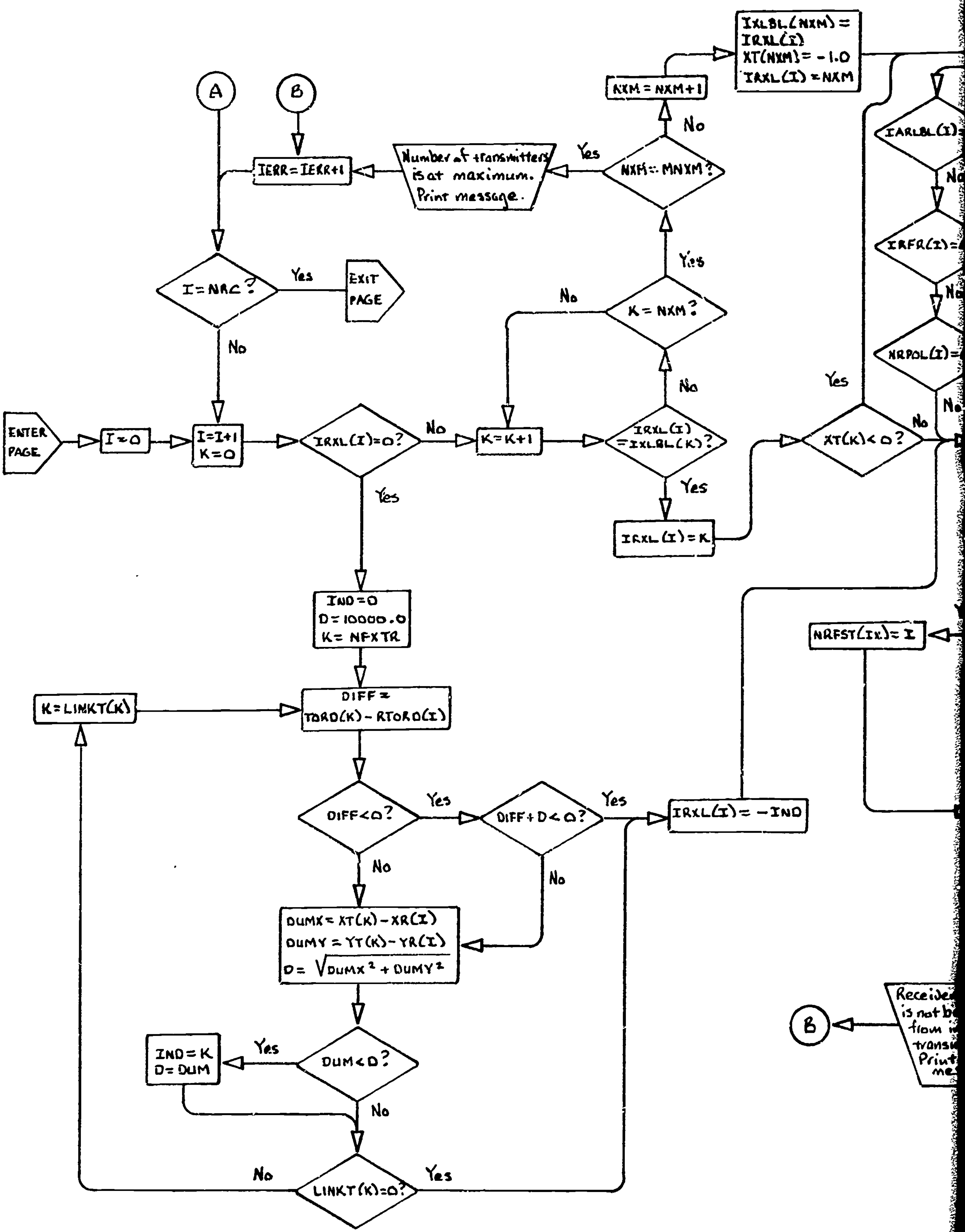
teristics by default or computation later in the program.

When the above tasks are complete, the receiver is linked to its group (i.e., its owning transmitter) using LINKR and the two transmitter variables NRFST and NRLST, and checked for an antenna label IARLBL. If this field is zero the analyst probably plans to have the antenna selected by the program (see 6.3). This can be verified by checking NFANT to ascertain that the ordered antenna list is not empty. If IARBLB is nonzero, a match must be found among antenna labels IALBL and index L stored in the receiver's antenna label position.

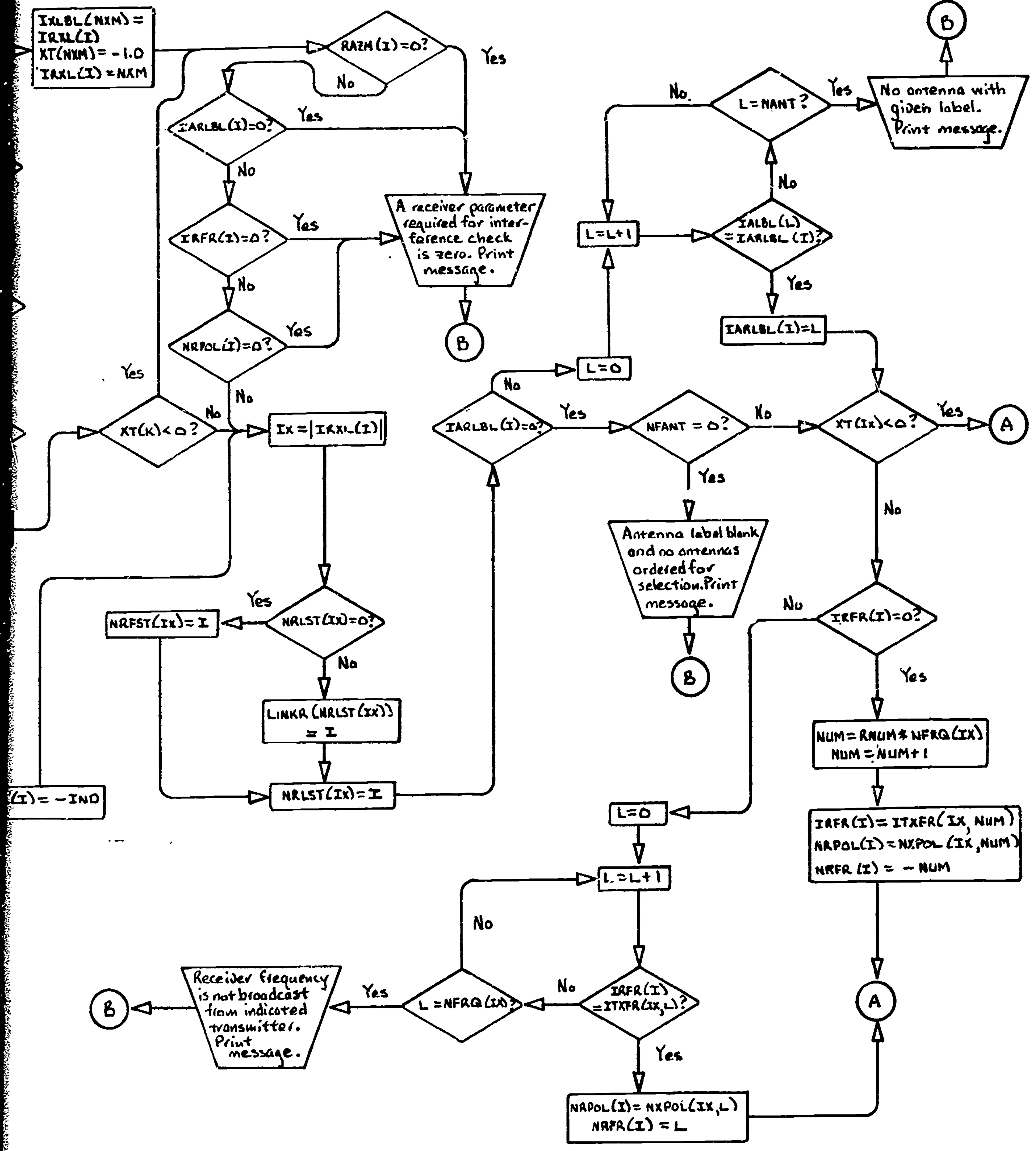
Processing for receivers owned by dummies ends at this point. The frequency field IRFR of other receivers is checked for zero. If the field is nonzero, the frequency table ITXFR for the owning transmitter is searched for a matching frequency and the index L for the match stored in NRFR. If field IRFR is zero, a frequency NUM is picked at random from those associated with the owner, and the negative of NUM is stored in NRFR.

The two negative values that may be stored in this section, IND and NUM, are to permit recognition (at "Print receiver identifying information..." in figure 50) and printing of the fact that IRXL and/or IRFR have been assigned to the receiver by default. These negatives should be eliminated immediately upon recognition.

Fig. 19 - LINK AND CHECK R



9 - LINK AND CHECK RECEIVER DATA



5.4 Link and Check Control Data

Problem variables originating in this portion of the program (figure 20) are defined below.

Definitions:

NGRSP - parameter describing any special control requests (SC cards) among receivers belonging to a transmitter (0 - no special controls, 1 - special controls request topography, 2 - special controls do not request topography).

NOBRD - parameter that is 1 if obstacle search requested, 0 otherwise.

NPLWR - parameter that is 1 if plot tape will be used, 0 otherwise.

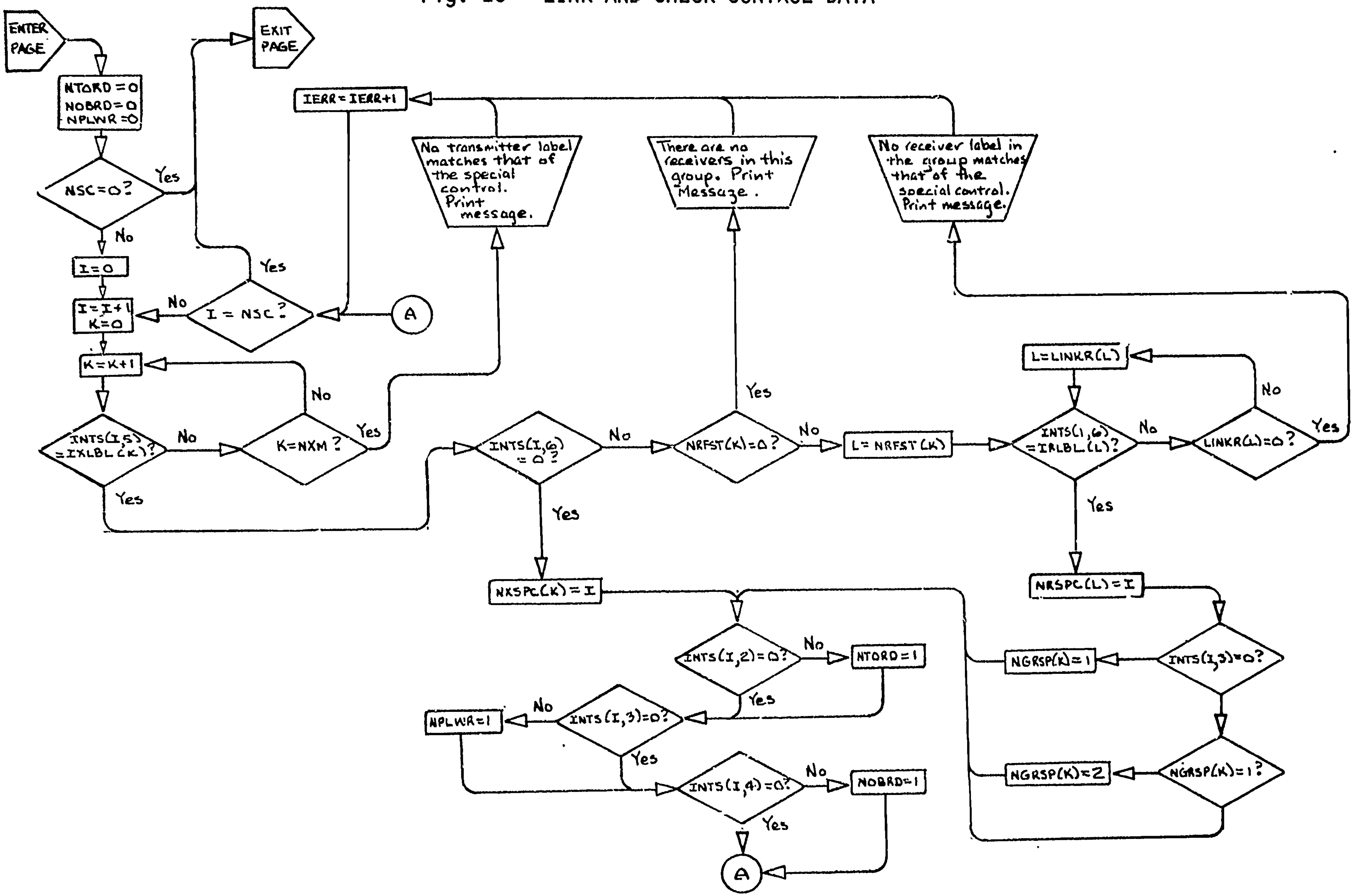
NRSPC - index of special control applying to a receiver.

NTORD - parameter that is 1 if topography computations will be made, 0 otherwise.

NXSPC - index of special control applying to a transmitter receiver group.

One objective here is to associate each special control request with the receiver or receiver group to which it applies by storing its index in NRSPC or NXSPC, respectively. The second objective is to determine what input and output devices will be required during computations by scanning computation parameters in each set of special controls. Results of the scan are recorded in NTORD, NOBRD and NPLWR defined above. The third objective is to indicate by means of NGRSP whether any receivers within a transmitter's group will be affected by special controls.

Fig. 20 - LINK AND CHECK CONTROL DATA



5.5 Input - Output Check

The input-output check shown in figure 21 scans general controls to determine their bearing on input and output devices, recording results in the variables defined in 5.4, NTORD, NOBRD and NPLWR. Then for each device (the topography file, the obstacle file and the plot tape) a test determines whether or not the device will be needed. If it will be, an additional test insures that parameters necessary to identify and use the device are available. These parameters are input on control card GC2 (figure 1).

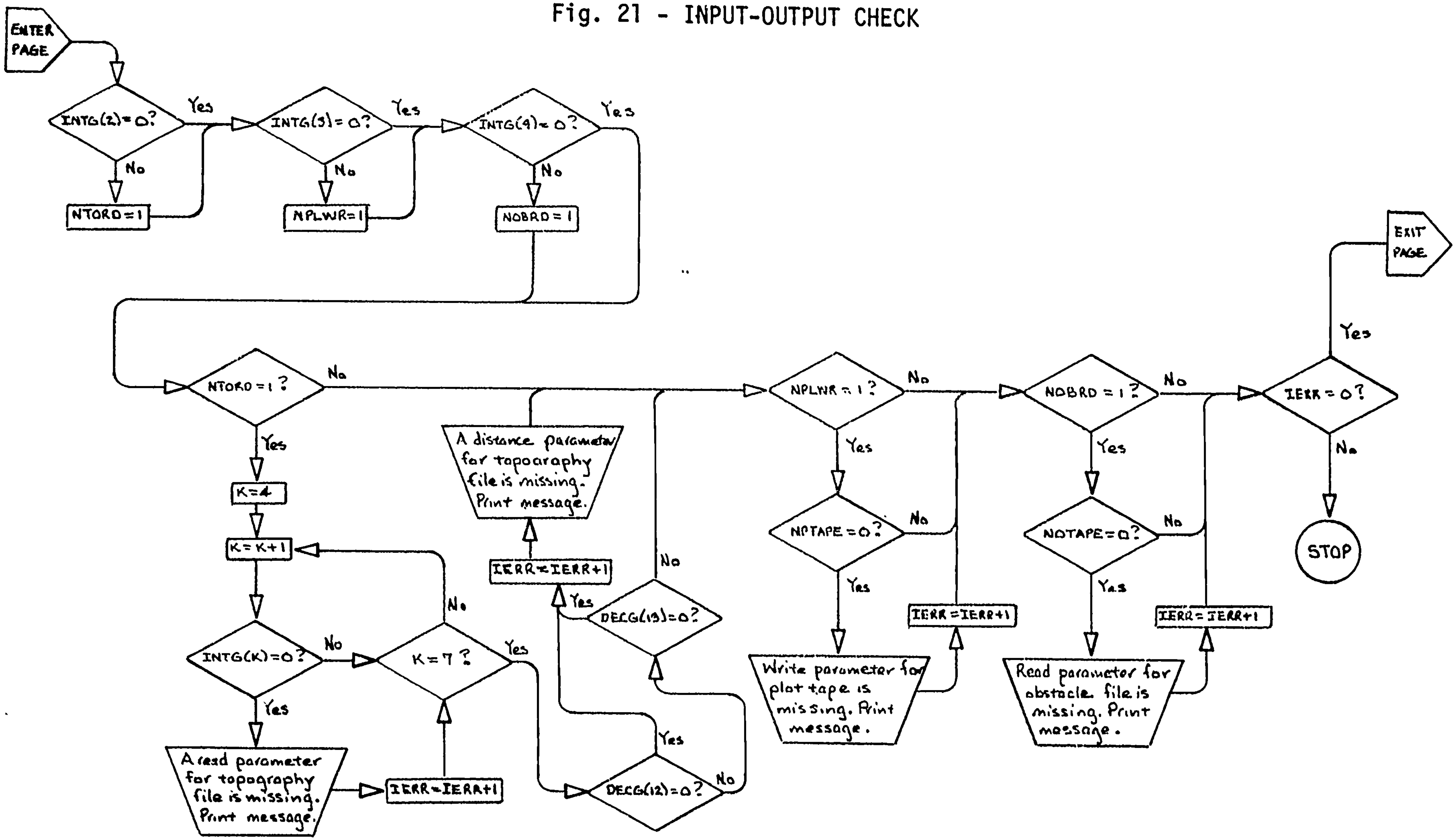
If any errors have occurred during the processing defined in 5.1 through 5.5, the program stops at this point. Otherwise, the program next reads the reference data it will need.

5.6 The Topography File

This program is designed to use a topography file composed of a physically rectangular array of terrain elevations NELEV (in feet above mean sea level) with uniform spacings DX in the positive X direction and DY in the positive Y direction. Variables DX and DY (read in on card GC2) are expressed in decimal fractions of a mile. The direction of the array's positive Y axis need not be true north; it is local north in the analysis. For this reason nonzero antenna azimuths TAZM and RAZM in the input data must be with respect to the direction of the positive Y axis of the topography file. In addition input coordinates of transmitters and receivers must be measured with respect to the file's origin, its lower left-hand corner.

The restrictions noted above are not severe. Values TAZM for omnidirectional transmitting antennas are zero regardless

Fig. 21 - INPUT-OUTPUT CHECK



of Y-axis orientation, and values RAZM are computed automatically by the program as required if not specified in the input data (see 6.3 and 6.7). Thus relatively few azimuths need be measured or computed outside the program.

In addition, satisfactory computerized topographic data covering metropolitan areas does not exist at present. The most practical method of constructing a topography file is to record elevations from a grid superimposed on U.S. Geological Survey 7.5 minute maps of the area to be studied. During this process receivers and transmitting locations involved in the analysis can conveniently be measured with respect to the grid origin.

Planning for a metropolitan area instructional television network is apt to proceed in stages, each stage corresponding to new requests for channels; additions to the topography file encompassing the areas involving the requests; and investigation using the program of tentative network points in the areas. When the topography file origin is altered during a stage, previously encoded transmitter and receiver coordinate values in the input data can be translated accordingly by incorporating in the program the simple features explained in 5.6.5.

The manner in which the topography file is handled within the program depends on its size, the amount of core storage available on the computer being used, and the speed with which external devices on which the file might be stored can be accessed. The program version presented herein assumes the entire topography

file can be put in core, since the writer is at present dealing with a relatively small file and a decidely large machine. However, alternative schemes covering the other possibilities are completely explained in the following sections.

Variables used in handling the topography file are defined in the remainder of this section. It should be pointed out that only elevation values of the file need to be stored in the machine. Values of the indices used to address elevation storage locations, coupled with the fact noted above that elevations are separated by uniform DX and DY, can be used to compute an elevation's physical position quickly without reference to any stored position information. Thus most of the variables below are index values of one sort or another employed in this process.

The amount of the file that the machine can handle in core is specified by:

NXMCH - maximum permissible range of topography file X index in the machine.

NYMCH - maximum permissible range of topography file Y index in the machine

The size of the file has been stated with NXTAB and NYTAB on card GC 2 (see 3.0).

The size of some segment of the file that is of current interest is described by:

NXRNG - range of topography file X index for segment involved..

NYRNG - range of topography file Y index for segment involved.

Description of the actual file segment in the machine requires four variables.

NXMAX - maximum X index of file segment in the machine.

NXMIN - minimum X index of file segment in the machine.

NYMAX - maximum Y index of file segment in the machine.

NYMIN - minimum Y index of file segment in the machine.

If the file segment in the machine does not include the origin, the real indices of elevations read from the topography file must be adjusted to properly address the elevations as stored in the machine.

NXADJ - factor by which X index of elevation is adjusted

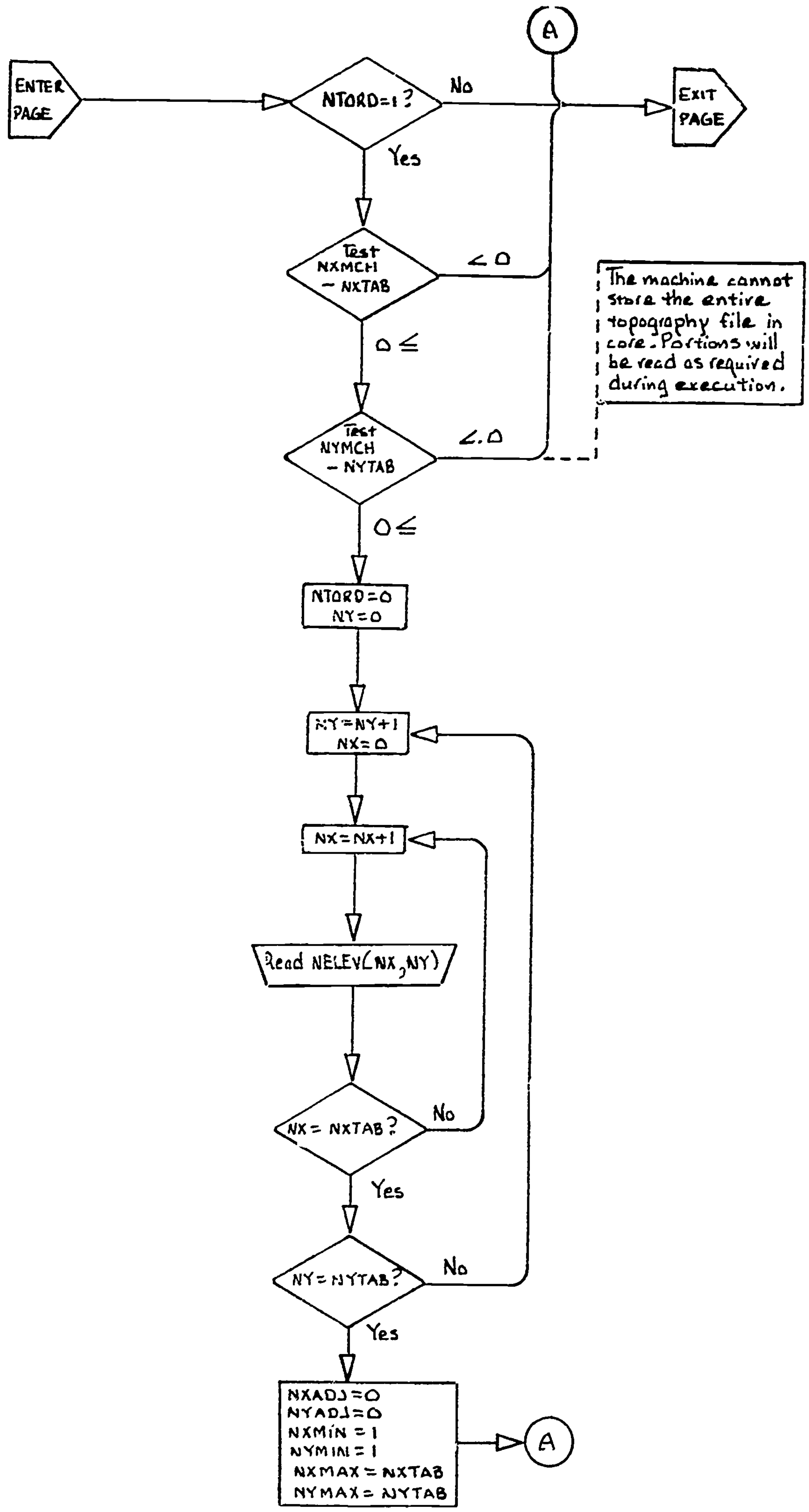
NYADJ - factor by which Y index of elevation is adjusted

The nature of the adjustments to be made is explained in 6.4. Figure 27 shows most of the above variables. The topography file is assumed to be stored by physical row; that is, such that for NELEV (NX, NY) the subscript NX varies most rapidly at any time the file is being read.

5.6.1 File in Core

The routine shown in figure 22 reads in the entire topography file before computations begin. The two tests on table dimension versus machine dimension are included to indicate that an alternate method of handling the file can, if desired, be included later in the program if the file will not all fit in the machine at once. As mentioned before, alternate methods are not actually shown in position in program flow diagrams, but what they are and where they would be placed are examined in 5.6.2 and 5.6.3.

Fig. 22 - READ TOPOGRAPHIC DATA
- FILE IN CORE - NTTAPE



5.6.2 File Segment in Core Centered on Transmitter

This scheme centers about a transmitter's location in the topography file a block of elevations equal in dimension to the space available in the machine. The scheme is useful if the programmer is handicapped in two ways - not enough core to store the entire file, and a relatively slow external storage device with which to communicate.

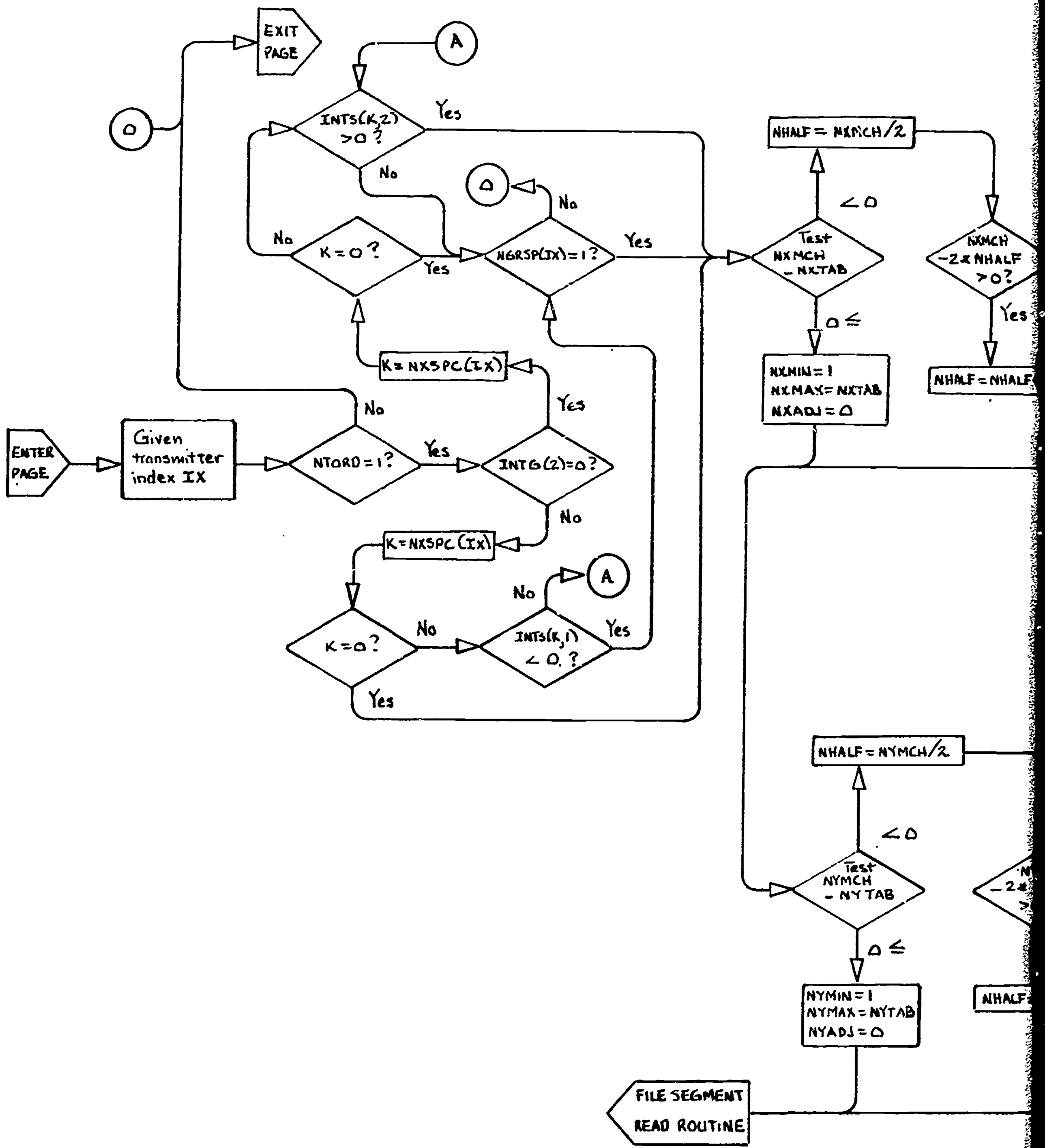
The logic involved is shown in figure 23 and the associated read routine in figure 26. The combination would be placed in figure 50 just after the output statement, "Print transmitter identifying...". This is the point at which it has been determined that computations of some sort must be done for members of the transmitter's receiver group. Thus the topography file is accessed at most once for each receiver group that requires processing.

In figure 23 the set of decision points at the left of the page determines whether general controls, special controls on the receiver group or special controls on individual receivers ask for topography computations. If not, no read is necessary. If so, the following additional variables are computed and used with those defined in 5.6 to center a block NXMCH by NYMCH about the transmitter owning the group.

NHALF -	the X (or Y) index representing the halfway point of storage available in the machine.
NXMX -	the X index of the file just "west" of the transmitter location.
NXMY -	the Y index of the file just "south" of the transmitter location.

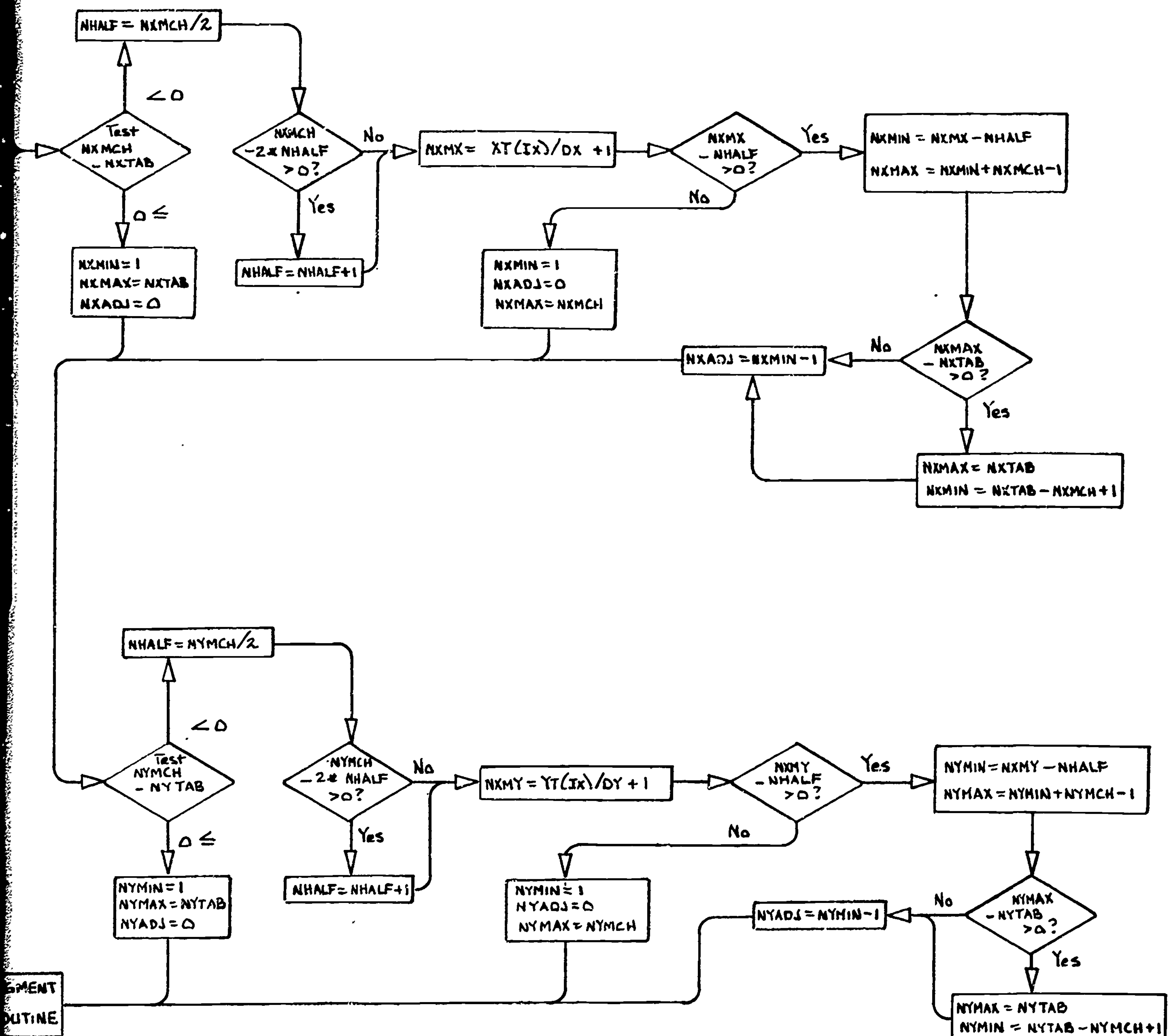
Fig. 23 - READ TOPOGRAPHIC DATA

-FILE SEGMENT IN CORE CENTERED ON



- READ TOPOGRAPHIC DATA

EGMENT IN CORE CENTERED ON TRANSMITTER



Operations XT(IX)/DX and YT(IX)/DY represent the largest integers contained in the resulting quotients.

Notice that centering about the transmitter is a compromise made necessary by slow access time to the external storage device. Some receivers served by the transmitter may lie outside the file segment defined in this manner, and it is even more probable that some interfering transmitters of interest lie outside. In these cases there is just not enough data in the machine to compute a complete terrain record, a fact which is recognized in the coordinate check, 6.4.

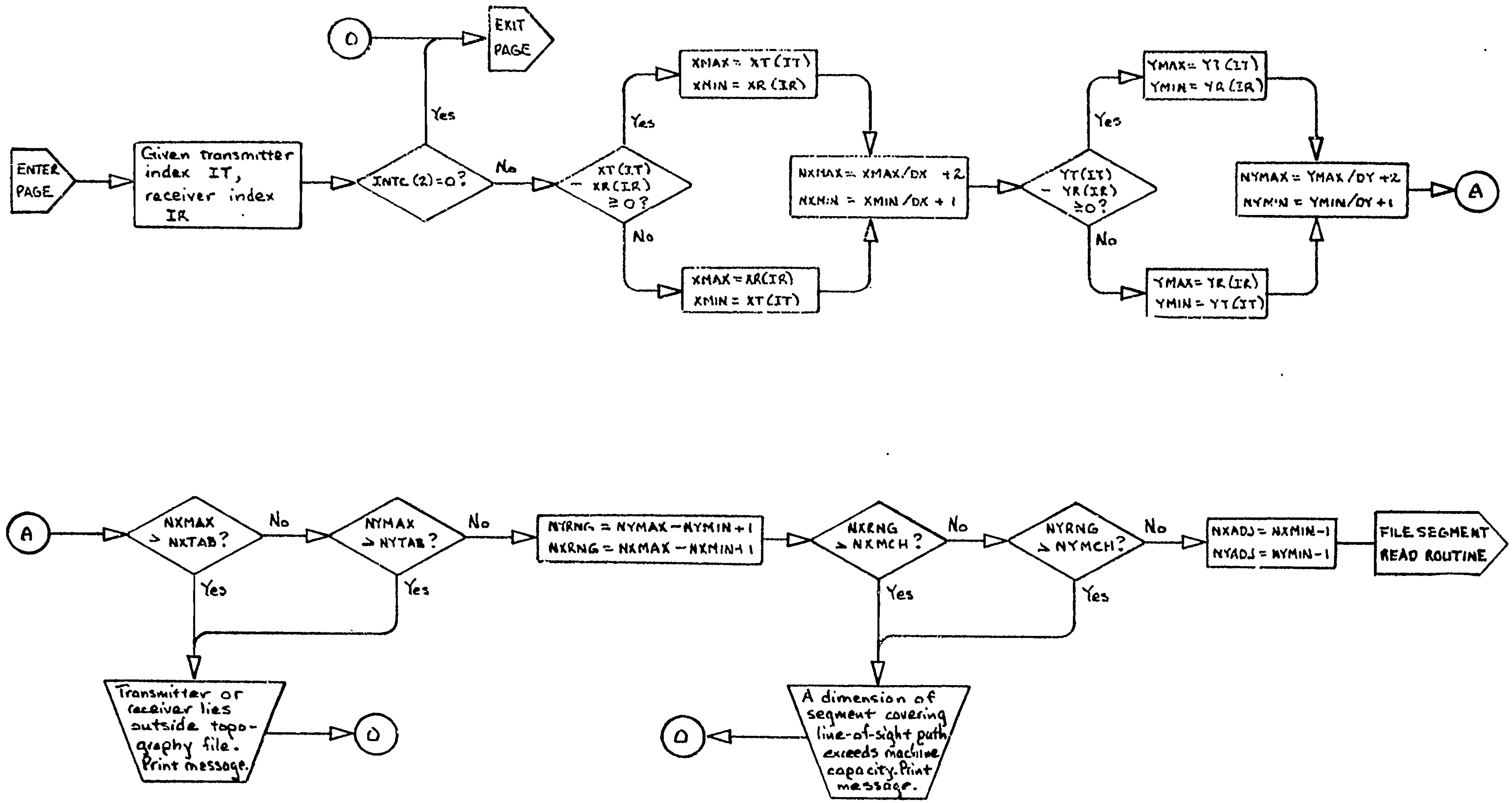
The file segment read routine is discussed in 5.6.4.

5.6.3 File Segment is Core Covers Line-of-Sight Path

This scheme is useful if the programmer is handicapped only by core storage, having available an external device with which communication is rapid. The scheme takes from the topography file a rectangular segment which just covers the transmitter and receiver of current interest.

Logic for this scheme is shown in figure 24. This routine and the read routine in 5.6.4 would be inserted at two points in the program. The first point is just prior to "Topography Factor Initialization and...." near the upper right hand corner of figure 50. The EXIT PAGE in figure 24 would lead to point D in figure 50. The second point were the two routines would be inserted is in figure 45 between "MTOP = 0?" and EXIT PAGE. In this instance the EXIT PAGE in figure 24 would lead to point D in figure 45. One additional alteration required is discussed in 6.7.

Fig. 24 - READ TOPOGRAPHIC DATA - FILE SEGMENT IN CORE COVERS TRANSMITTER - RECEIVER LOS PATH



In figure 24 the four coordinates of the two locations involved are re-identified as follows:

XMAX - "eastern most" of the two X coordinates XT, XR

XMIN - "western most" of the two X coordinates XT, XR

YMAX - "northern most" of the two Y coordinates YT, YR

YMIN - "southern most" of the two Y coordinates YT, YR

The re-identified coordinates are converted to a set of indices bracketing the transmitter and receiver in the topography file, a check is made to see that ranges and maximum indices are acceptable; and the file segment read routine is entered.

This scheme is more satisfactory than 5.6.2 if a fast peripheral storage device is available. The topography file is read once for each transmitter-receiver pair requiring topography computations. A simple comparison of the physical difference between the two schemes is shown in figure 25.

Fig. 25 COMPARISON OF FILE READ SCHEMES

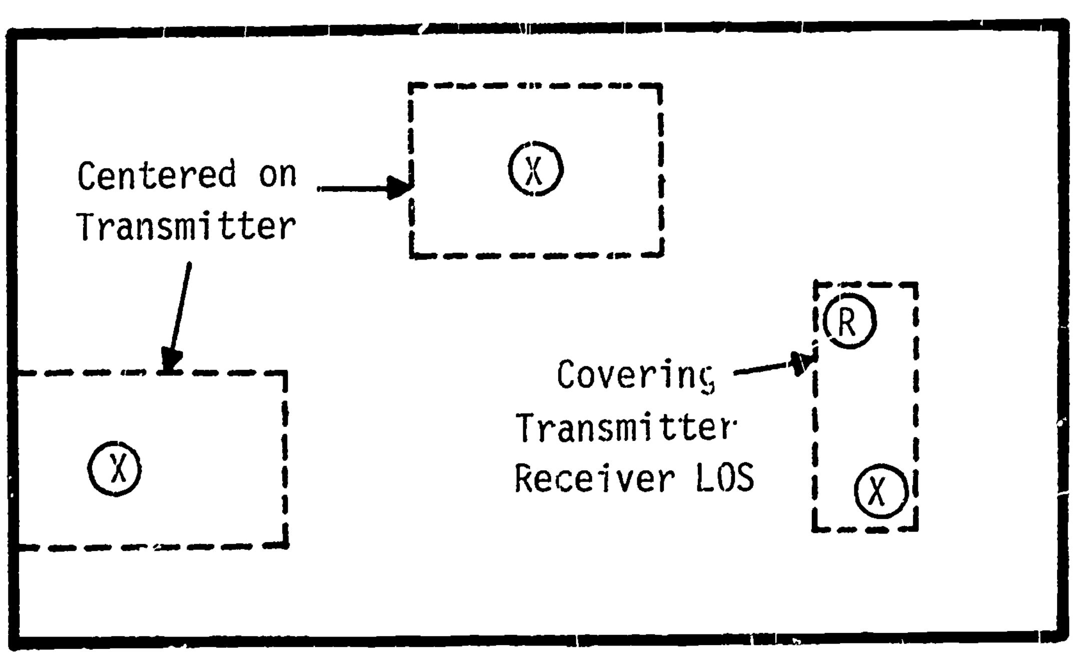
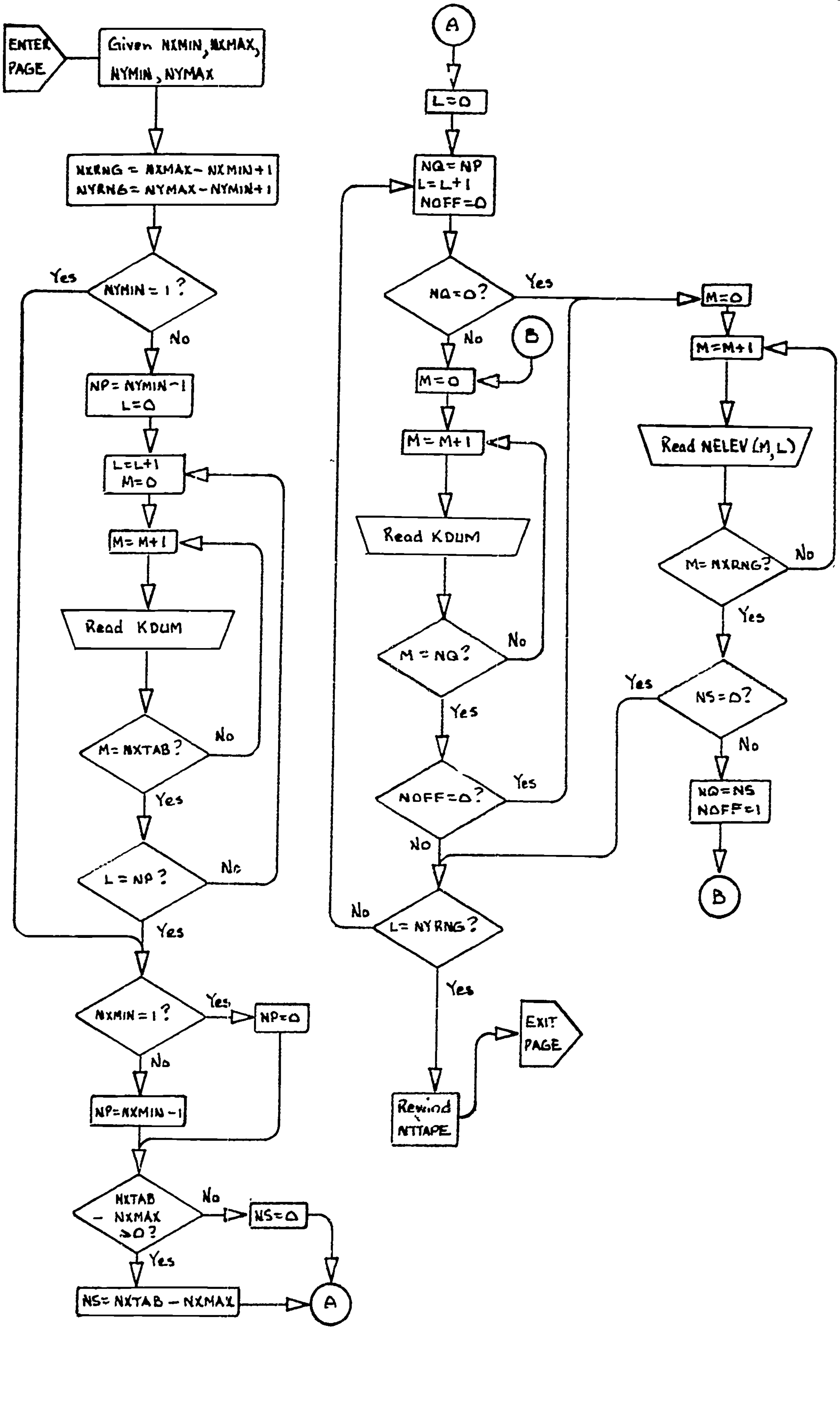


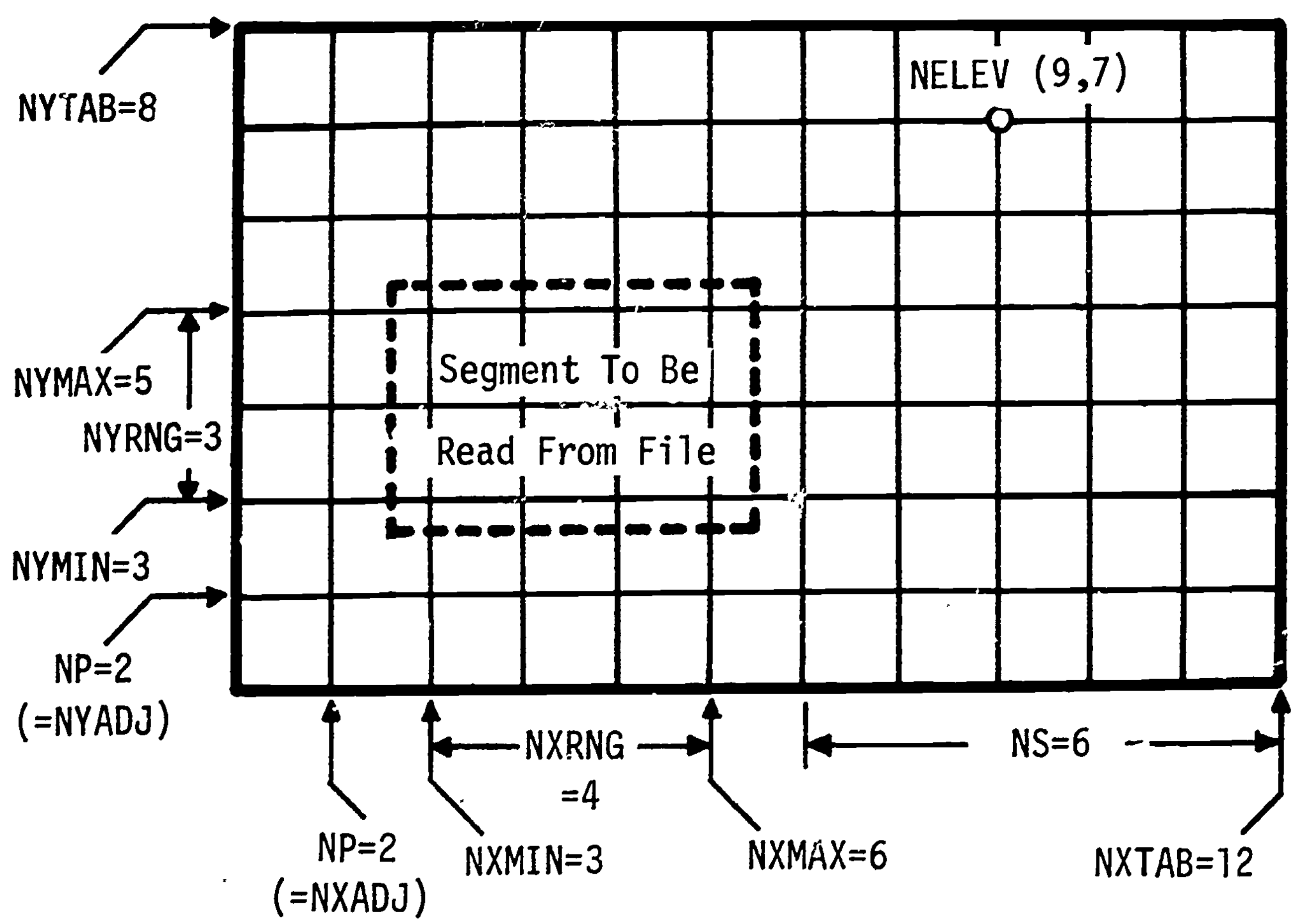
Fig. 26 FILE SEGMENT
READ ROUTINE-NTTAPE



5.6.4 File Segment read Routine

Figure 26 is a flow chart of the file segment read routine, and figure 27 shows the variables involved. In brief the left hand column in figure 26 reads without storing through rows that do not include elements in the segment defined (i.e., upward in figure 27 through the first NP rows). For the next NYRNG rows in figure 27, the center column in figure 26 reads to the right without storing through the first NP elements of each row (NP having been redefined as NXMIN-1). The right hand column stores the portion of each row that belongs to the segment (NXRNG elements). Then the center column continues through the remaining NS elements of each row without storing. When the topmost row containing elements of the segment has been read, the topography file device is rewound.

Fig. 27 VARIABLES IN FILE SEGMENT READ ROUTINE



5.6.5 Transmitter and Receiver Coordinate Translation

As noted in 5.6 above, changing the origin of the topography file may make coordinates on X and R cards incorrect. Any change in the origin that consists of a simple translation of axes can be taken into account with the measures shown in figure 28. In TXLTE (4.3) and RXLTE (4.4) make two additional card types recognizable, XLTE and ENDT. Place an XLTE card preceding and ENDT card following each group of transmitters (X cards) and/or receivers (r cards) with outdated coordinates. Let

XLX = translation currently in effect along X axis, and

XLY = translation currently in effect along Y axis.

On each LXTE card place the desired axis translations. As shown at the bottom of figure 28 all coordinates processed by XXLTE or RXLTE have XLX and XLY applied. The XLTE card inserts the proper translations for transmitters or receivers behind it in the data, and ENDT stops translation by setting XLX and XLY to zero.

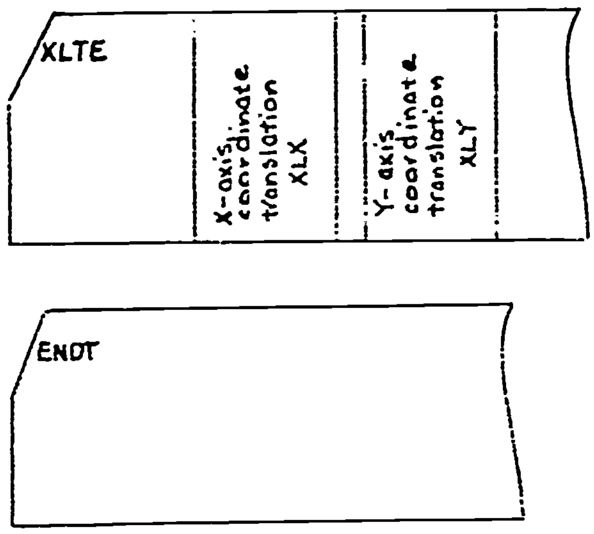
5.7 The Obstacle File

The program checks line-of-sight paths against a list of man made and unusual natural obstacles if desired. Each obstacle is defined by a set of coordinates (with respect to the origin used in the analysis) and an effective radius. If any portion of a line-of-sight path is a chord of a circle with an obstacle's coordinates as center and its given effective radius, the program notes that obstacle as a possible interference source for the path in question.

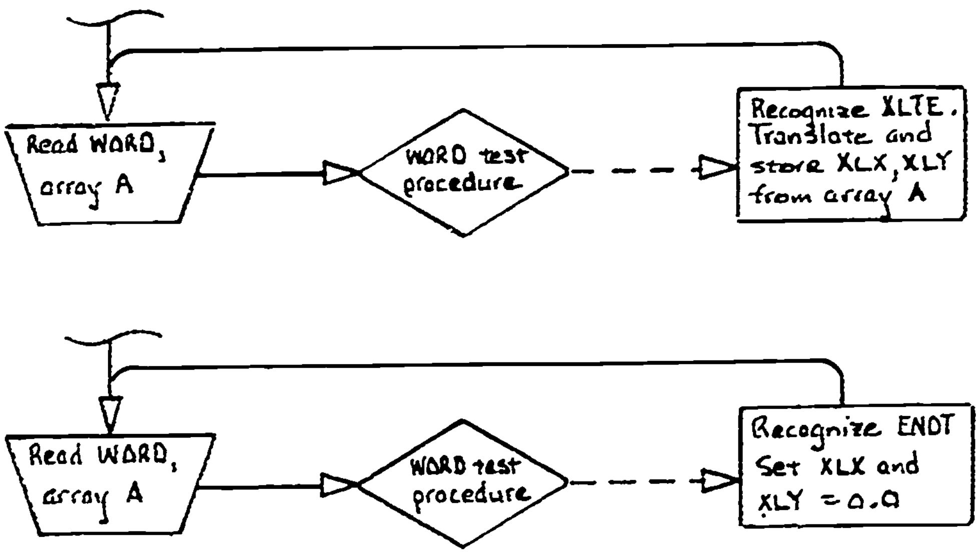
Figure 29 shows how the obstacle file is read and arranged

Fig. 28 - TRANSMITTER AND RECEIVER COORDINATE TRANSLATION
- CHANGE OF TOPOGRAPHY FILES

CARD TYPES

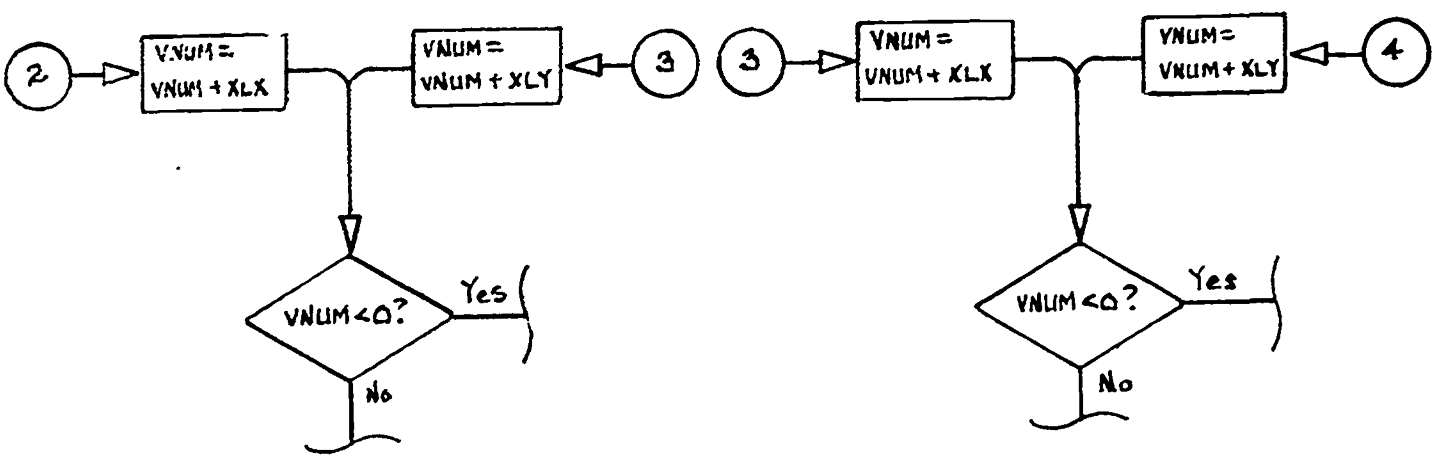


TASKS IN XXLTE AND RXLTE



XXLTE COORDINATE BRANCHES

RXLTE COORDINATE BRANCHES



if it will be required during computation. Variables used are defined below.

Definitions:

LINKO -	index of successor to a member of the ordered obstacle list.
NBOORD -	array of members heading the NSOORD sections of the ordered list
NFOBS -	first obstacle in the ordered list
NOB -	number of obstacles in the file
NOBMX -	maximum number of obstacles allowed (Programmer supplied)
NSOORD -	number of sections into which the ordered list is divided.
O -	obstacle coordinate array not used in ordering obstacles.
OORD -	obstacle coordinate array used in ordering obstacles
R -	effective radius of obstacle
RMAX -	maximum effective radius found in obstacle data.
RO -	receiver array corresponding to coordinate not used in ordering obstacles.
ROORD -	receiver array corresponding to coordinate used in ordering obstacles
TO -	transmitter array corresponding to coordinate used in ordering obstacles
XO -	obstacle X coordinate
TOORD -	transmitter array corresponding to coordinate used in ordering obstacles

XOMX - maximum XO found in obstacle data

XORNG - difference between maximum and minimum XO's found in obstacle data.

YO - obstacle Y coordinate

YOMN - minimum YO found in obstacle data

YOMX - maximum YO found in obstacle data

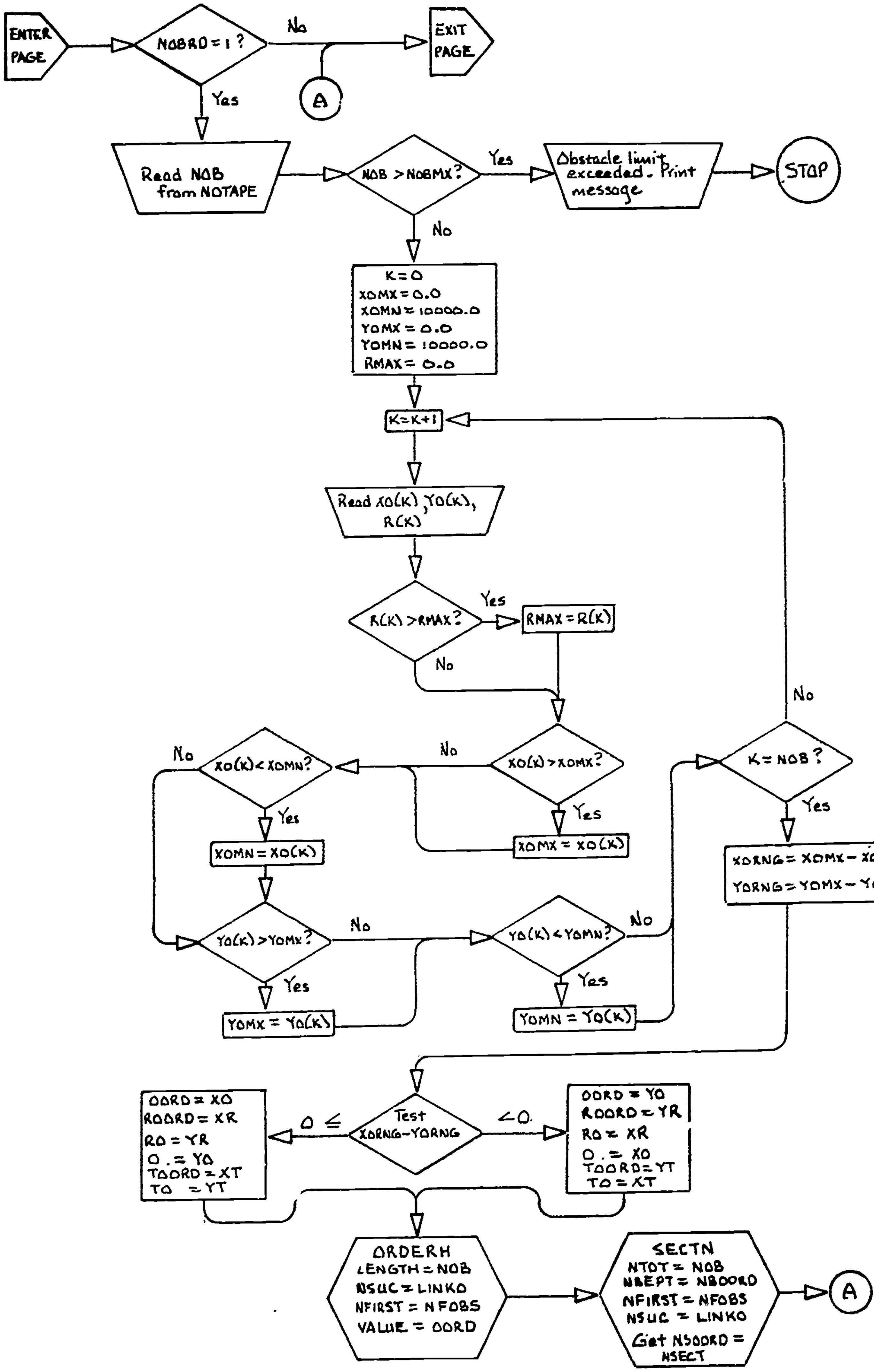
YORNG - difference between maximum and minimum YO's found in obstacle data

In figure 29 the effective radius R of each obstacle is tested against the maximum RMAX so far found (and supercedes it if greater supercede) the maximum and minimum so far found for each coordinate. When information for all obstacles has been read and tested in this manner, ranges XORNG and YORNG are computed. Transmitter and receiver arrays corresponding to the obstacle coordinate OORD with larger range are marked, and the obstacle list is ordered on OORD, then divided into sections.

The rationale behind ordering obstacles is similar to the explanation in 5.2 regarding transmitters. RMAX for obstacles corresponds to DISTO for interfering transmitters. The difference is that while transmitter interference is investigated at a single point (the location of receiver R), obstacle interference must be checked along a line-of-sight. Thus the length of the physical interval of interest in searching for obstacles in the ordered list is 2RMAX + /TOORD (IT) - ROORD (IR)/ as opposed to 2DISTRO for interfering transmitters.

Use of the ordered and sectioned list resulting from ORDERH and SECTN at this point is explained in 7.2.

Fig. 29 - READ AND ORDER OBSTACLE DATA - NOTAPE



6.0 Computations

Various minor processes used at several points in the program are treated together in 6.1 and 6.2. In sections following 6.2 the major computations made in the program are examined individually. Most details of the sequence in which major computations may be executed are covered in sections of 7.0. However, 6.7, which explains interfering transmitter computations, contains as a matter of convenience the details of how topography computations are associated in the program with investigation of interference situations.

6.1 Processes Involving Decibels, Power and Power Ratio

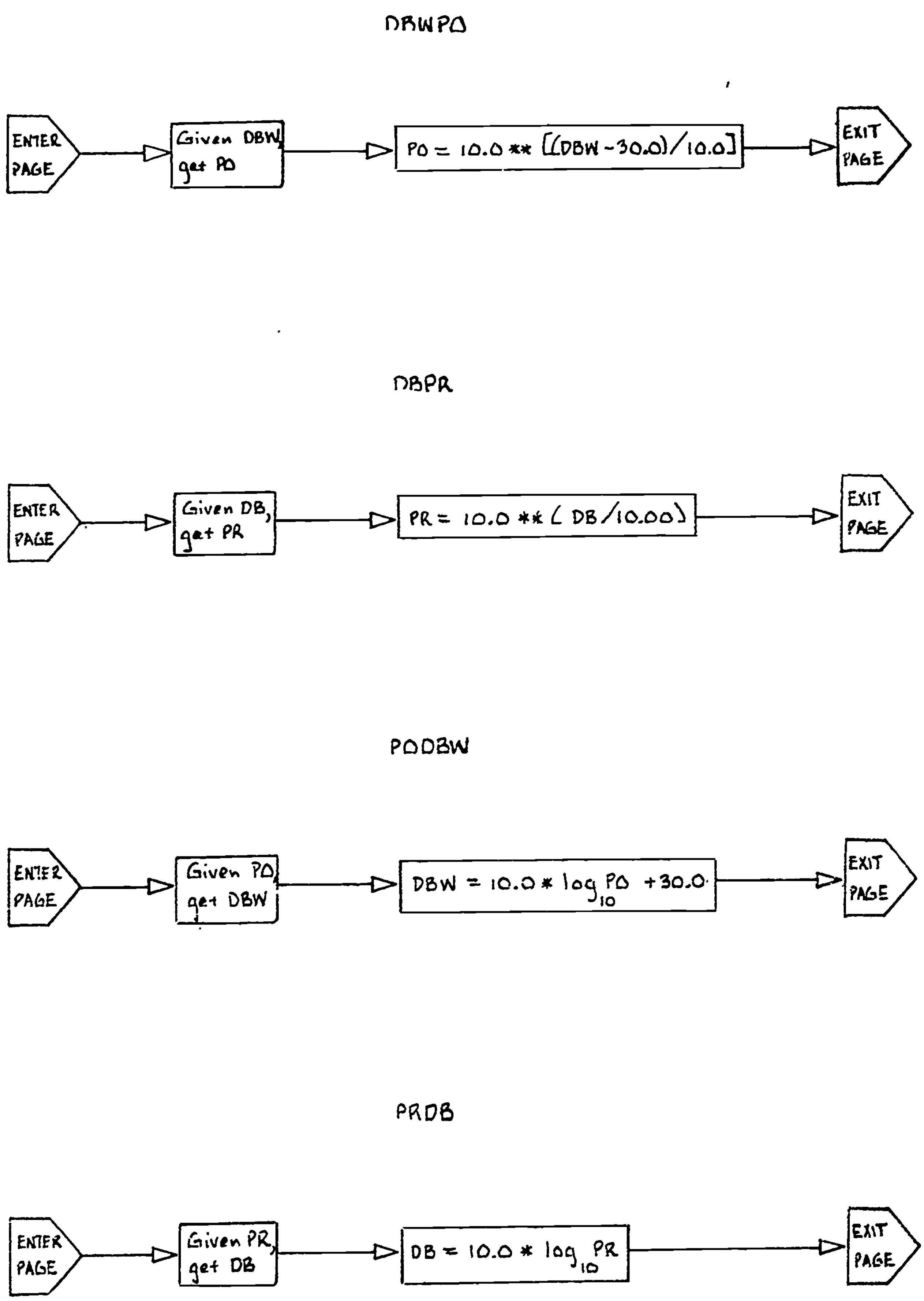
In the program transmitted (XPWR), received (RIPWR), interference (TI) and noise (ENPO) power are for the most part computed or used in the units, watts. But it is more convenient to specify some input data and inspect results in the units, decibels or dbm. The processes shown in figure 30 perform conversions among watts, decibels and dbm. The common relationship in all the processes is:

$$\text{Power Ratio (decibels) or Power (dbm)} = 10 \log_{10} P_1/P_2$$

Where P_1 and P_2 are two signal powers (expressed in watts). If the power of a single signal is to be converted from watts to dbm, P_2 is assumed to be 1 milliwatt (.001 watt). Thus in figure 30,

1) DBWPO converts power DBW in dbm to PO in watts,
2) DBPR converts power ratio DB in decibels to PR (no units),
3) PODBW converts power PO in watts to DBW in dbm, and
4) PRDB converts power ratio PR (no units) to DB in decibels.

Fig. 30 PROCESSES INVOLVING DECIBELS, POWER AND POWER RATIO



The constant 30.0 appearing in the second and fourth processes comes from the assumption P_2 = .001.

6.2 Processes Involving Bearings and Azimuths

In computing gains with antenna tables and directions TAZM and RASM of receiver antenna centerlines, the program uses three processes shown in figure 31.

BCOMP computes the bearing BERNG from local north to a transmitter, taken at the location of a receiver. Variables in BCOMP are shown in figure 32. It is assumed that function ARCOS returns an angle in radians, and that the angle lies between $\pi/2$ and π if the argument furnished is negative.

BREV takes a given bearing BIN and reverses it, π radians to BOUT

BREL computes a relative bearing BERNG from one given azimuth FRM to a second given azimuth TO. Variables in BREL are shown in figure 33.

6.3 Receiver Signal and Noise Power Computations

The signal strength or power at a receiver is a product (literally, in the mathematical sense) of several factors. The product is explained below in terms of variables shown in fig. 34.

Broadcast power at the transmitter is XPWR watts. Enroute to the antenna power is attenuated by the inverse of factor:

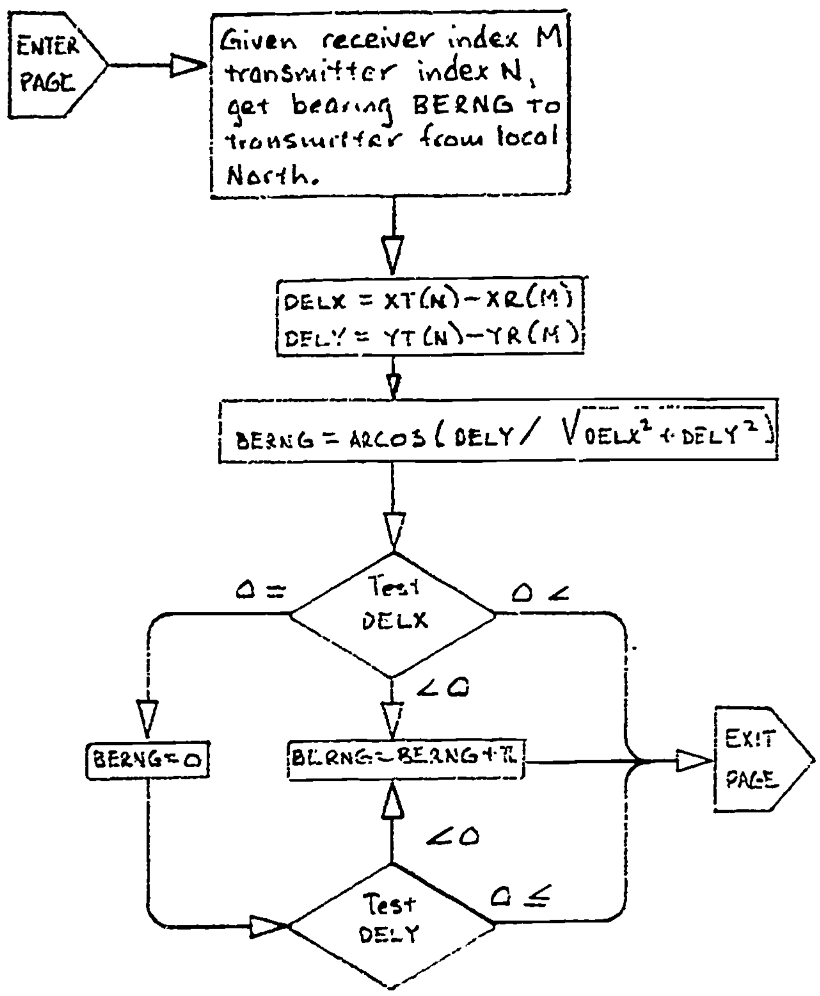
LT = transmitter line loss, expressed as ratio

At the transmitter antenna the signal is multiplied (in the direction of the receiver of current interest) by gain:

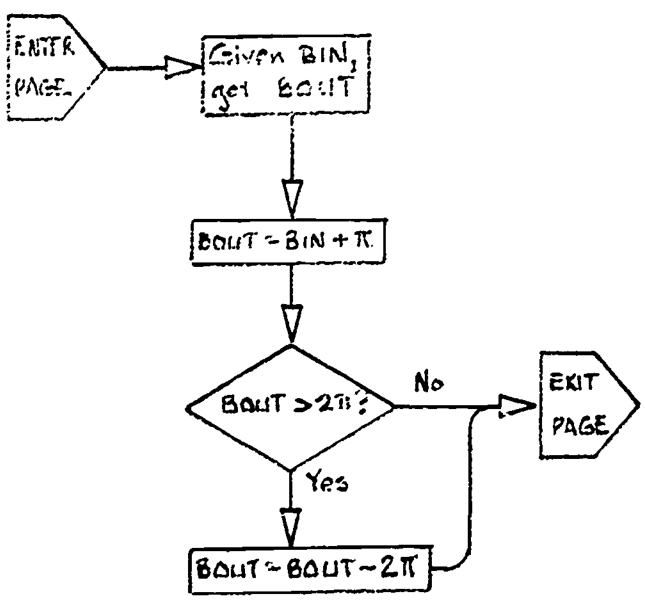
GT = transmitter antenna gain in direction of receiver expressed as a ratio.

Fig. 31 - PROCESSES INVOLVING BEARINGS AND AZIMUTHS

BCOMP



BREV



BREL

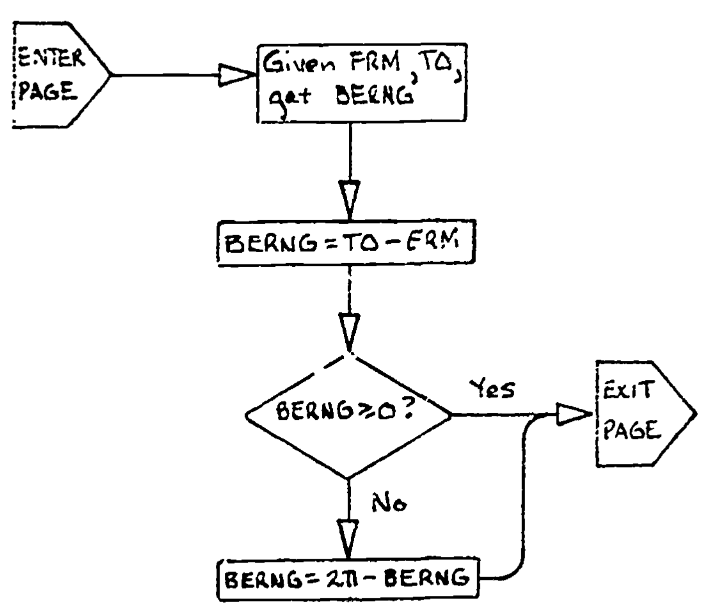


Fig. 32 VARIABLES IN BCOMP

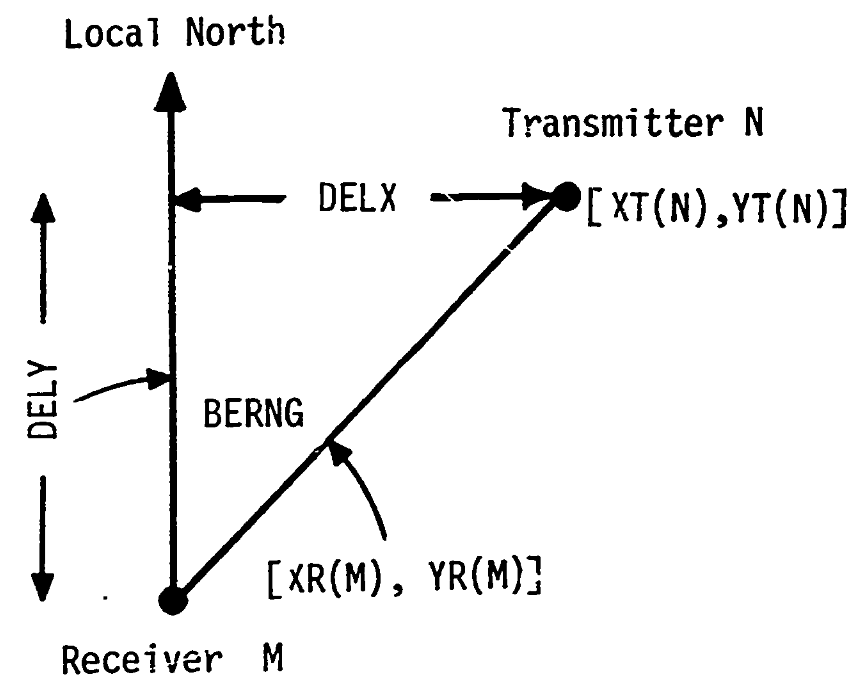
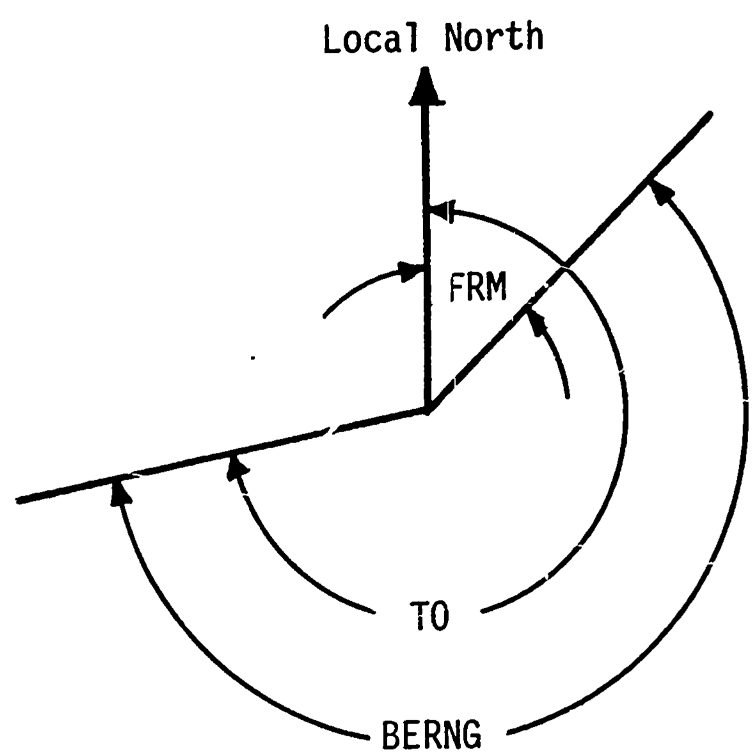


Fig. 33 VARIABLES IN BREL



In space the signal is attenuated with distance by the factor:

$$\text{Path Loss} = \frac{CLGHT^2 \times FM}{16\pi^2 \times D^2 \times IRFR^2}$$

Where D = distance from transmitter to receiver, miles

CLGHT = speed of light, megamiles/sec.

IRFR = receiver frequency, megacycles (input in 4.4)

FM = fading margin allowance

The fading margin allowance FM is itself defined as:

$FM = 10^{-XD}$

where X = constant (suggested value .5, see 3.0)

At the receiver antenna the signal is again multiplied by gain:

GR = receiver antenna gain in direction of transmitter, expressed as a ratio

Enroute to the receiver the signal is attenuated by the inverse of factor:

LR = receiver line loss, expressed as a ratio.

The product of these terms is the power at the receiver in watts, RIPWR.

A receiver has an inherent noise level which may be thought of as a signal with equivalent power:

ENPO = 4.0 x 10 x^{15} RNBW (DBPR(RNS)-1.0)

where ENPO = receiver equivalent noise power, watts

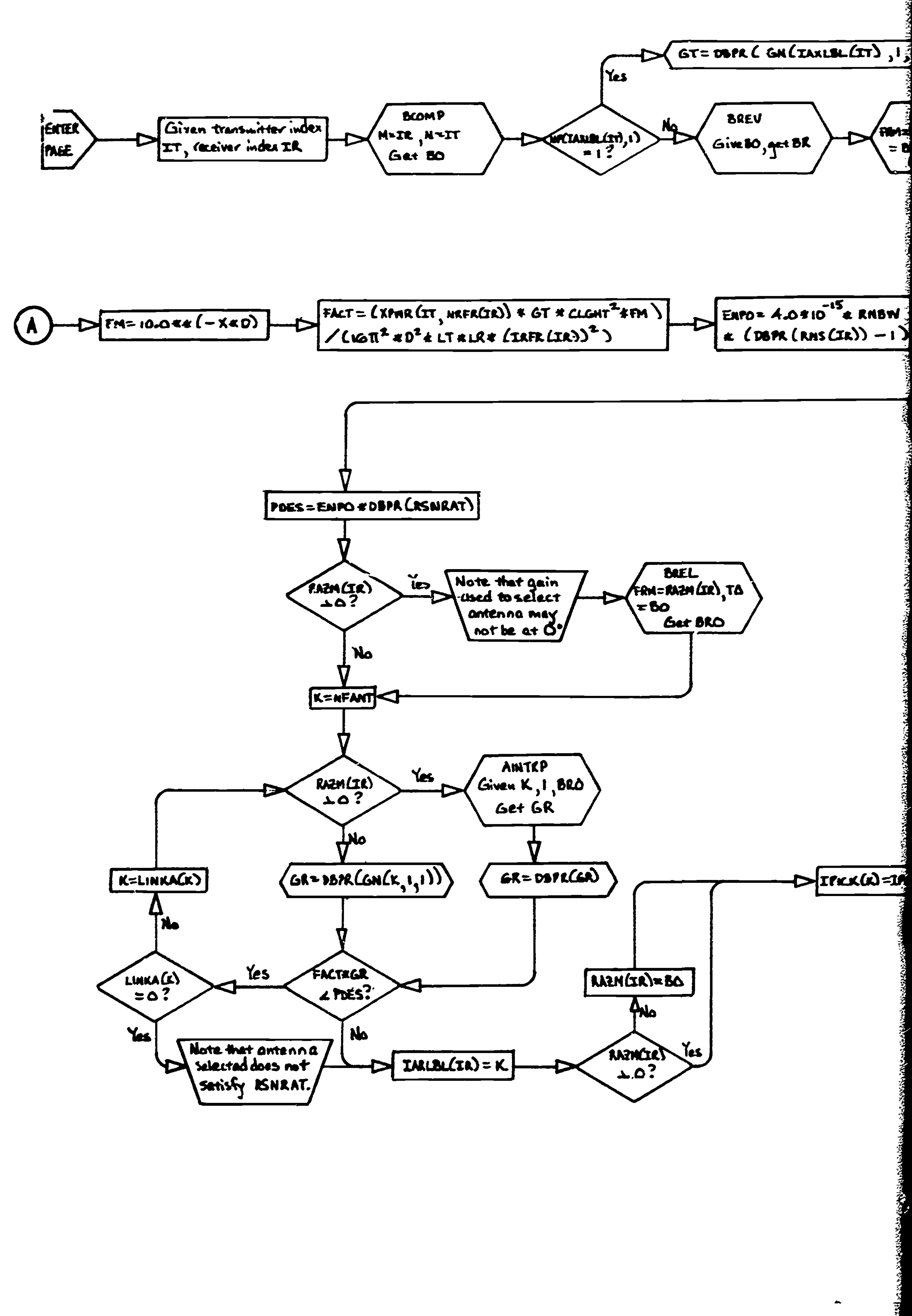
RNBW = receiver noise band width, megacycles (suggested value 6.0, see 3.0)

RNS = receiver noise figure, decibels (input in 4.4)

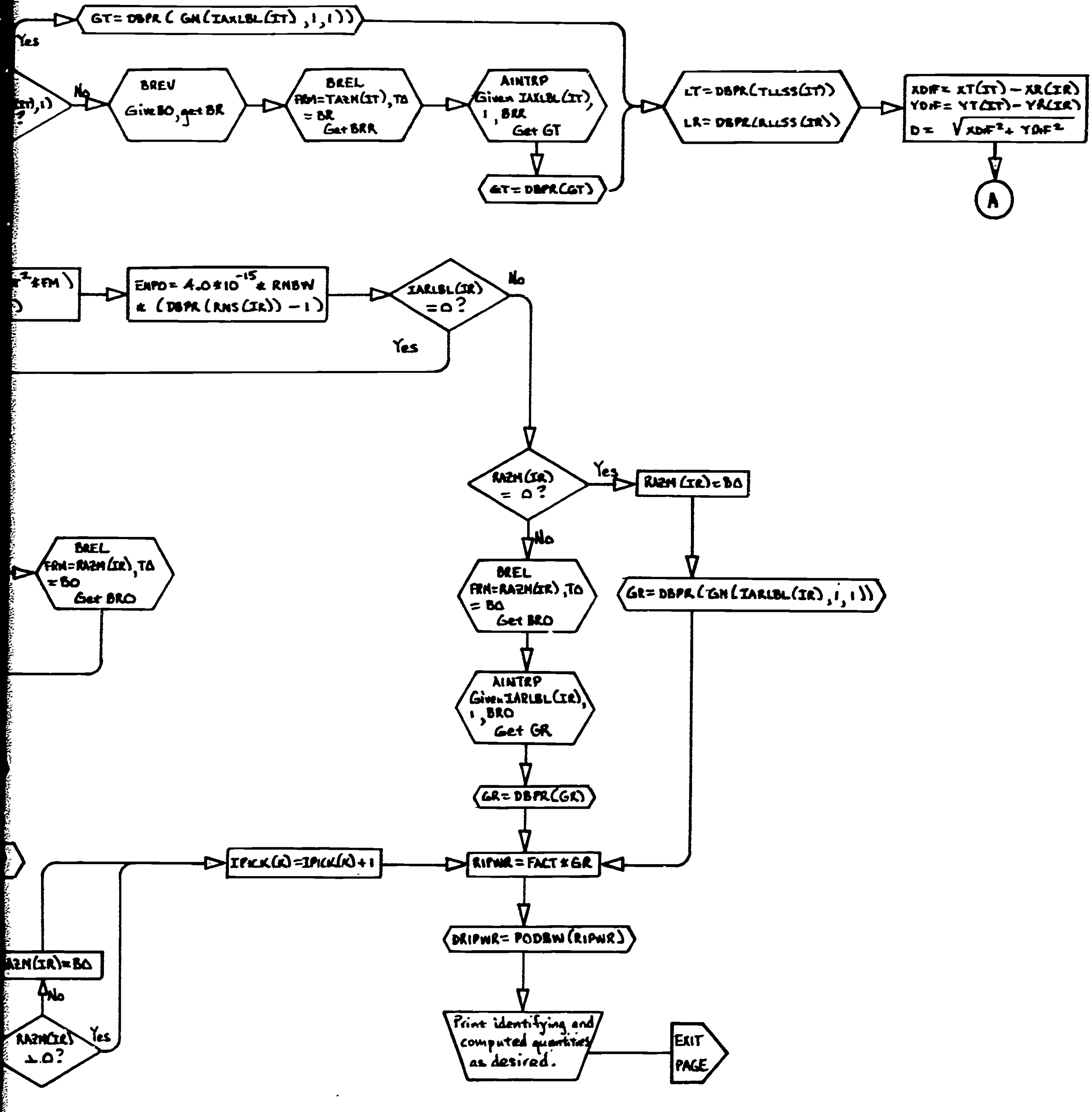
DBPR = process defined in 6.1

With these formulas in mind and the additional variables defined below, the computations in figure 34 can be

Fig. 34 - RECEIVER SIGNAL AND NOISE



RECEIVER SIGNAL AND NOISE POWER COMPUTATIONS



followed without difficulty. Variables not listed below have been previously defined.

Definitions:

BO - bearing from local north to owning transmitter at receiver.

BR - bearing from local north to receiver at transmitter.

BRO - relative bearing from receiver antenna 0^o line to owning transmitter at receiver.

BRR - relative bearing from transmitter antenna 0^o line to receiver at transmitter.

DRIPWR - signal power at the receiver in dbm.

FACT - product of all factors composing RIPWR except GR.

IPICK - counter for number of antennas of each type (in ordered list) selected by program for a given transmitting location.

PDES - power in watts desired at receiver according to RSNRAT criterian (see 3.0).

The transmitter and receiver indices IT and IR are given. Bearing BO to the transmitter is computed first. If the transmitter antennas primary polarization contains but one point, it is omnidirectional with one gain GT. Otherwise bearing BR and relative bearing BRR must be computed, then GT obtained by interpolation in the transmitter antenna primary polarization table. Construction of the interpolation routine AINTRP for antenna tables has been left to the programmer. Next LT and LR are converted from input data, and in order D, FM, FACT and ENPO are computed.

If at this point the receiver antenna label IARLBL is not zero, the receiver antenna azimuth RAZM is tested. A zero value for RAZM causes the program to store BO in RAZM and assume that GR is the receiver antenna's gain at 0^o primary polarization. If RAZM is not zero, the antenna's direction was fixed in the input data and GR is found by interpolation. RIPWR and DRIPWR are then computed.

When IARLBL is zero, the program will select an antenna for the receiver. The program uses previously computed ENPO and the input value RSNRAT to arrive at the desired signal power PDES at the receiver. It's task is now to search through the ordered antenna list beginning with NFANT until it finds a GR such that FACT *GR equals or exceeds PDES. Ordering the list with lowest 0^o primary polarization gain best (i.e., first in the list) means in effect that the antenna picked is the smallest that meets the RSNRAT requirement.

The combination of zero antenna label IARLBL and fixed direction RAZM is probably an input error; the program will make the computations after flagging this circumstance. If no adequate antenna can be found the program assigns the last (probably the largest physically) in the list by default.

Output quantities from these computations might include DRIPWR, POD_BW (ENPO), BO (if computed) and IARLBL (if chosen). The latter two events have to be flagged for the print routine since they cannot be recognized after the fact.

6.4 Topography Computations

The topography computations are first described here in general terms. Then the variables involved are defined and the routine is covered in detail with references to the appropriate figures. This should enable the reader to understand what transpires.

Given a transmitter IT and a receiver IR, the routine determines for each, based on its location (i.e., its coordinates) a special reference point in the topography file. The reference point for a location is the closest elevation NELEV lying in the same quadrant as the line-of-sight path to (or from) the location. The transmitter reference point is used to compute necessary initial values. Then the routine computes a distance from transmitter and a terrain elevation at each point where the line-of-sight path crosses any imaginary grid line drawn:

1) between two adjacent points in the topography file, and
2) parallel to the topography file's X or Y axis.

The distance - elevation pairs computed in this manner are stored in a "terrain record". The receiver reference point is used to end this phase of the computations.

The routine next finds the point in the terrain record which is most likely to obstruct the line-of-sight path. This "worst" point depends on the antenna height for the transmitter frequency IF under consideration. Then using the elevation of the worst point and its distance from the transmitter, the routine computes the antenna height at the receiver necessary to provide assumed constant Fresnel zone clearance FZCL at the worst point.

Finally, if the receiver antenna height has been specified prior to entering the routine, the routine computes actual clearance at the worst point of the path between the transmitter and receiver antennas.

A list of the variables originating in or confined to the topography computations is defined below.

Definitions:

DIFF - segment of distance DX or DY used in interpolating between elevations NELEV.

HLOSO - clearance of line-of-sight path between antennas at the worst point in the terrain record.

HLOSR - antenna height required at receiver to provide clearance FZCL at worst point in terrain record.

HLOST - elevation of line-of-sight at transmitter.

IW - index of worst point in the terrain record.

NELEV - a reference terrain elevation in the topography file.

NTPNT - number of points in terrain record.

NX, NY - indices of point NELEV being tested as possible end point of grid line intersected by line-of-sight path.

NXF, NYF - integer factors applied to make terrain record computations move "upword and to the right" (see figure 35) from transmitter to receiver regardless of their actual orientation.

NXMNC, NXMXC - minimum and maximum X indices in rectangular topography file segment just enclosing transmitter and receiver.

NYMNC, NYMXC - minimum and maximum Y indices in rectangular topography file segment just enclosing transmitter and receiver.

NXR, NYR - indices of receiver reference point in topography file.

NXT, NYT - indices of transmitter reference point in topography file.

THGT - elevation of terrain at intersection of line-of-sight path with a grid line of the topography file

TDIST - distance from transmitter to intersection of line-of-sight path with a grid line of the topography file.

WORST - smallest ratio (HLOST-THGT)/TDIST found in topography file.

XBEG, YBEG - distances from transmitter location to lines through its reference point parallel to Y axis and X axis, respectively.

XDIST, YDIST - signed differences (changed later to absolute values) between X and Y coordinates, respectively of the transmitter and receiver.

XDUM, YDUM - distances from transmitter Y and X coordinates, respectively, to corresponding coordinates of line-of-sight path intersection with a grid line.

XF, YF - decimal factors applied to make initial values XBEG and YBEG positive regardless of transmitter-reference point orientation.

XINT - a ratio (HLOST-THGT)/TDIST to be tested.

XSEC - secant of acute angle between line-of-sight path and topography file X-axis.

XTAN - tangent of acute angle between line-of-sight path and topography file X-axis.

XTOT, YTOT - distances from transmitter X and Y coordinates, respectively, to corresponding coordinates of point with indices NX, NY (see above definition of these indices).

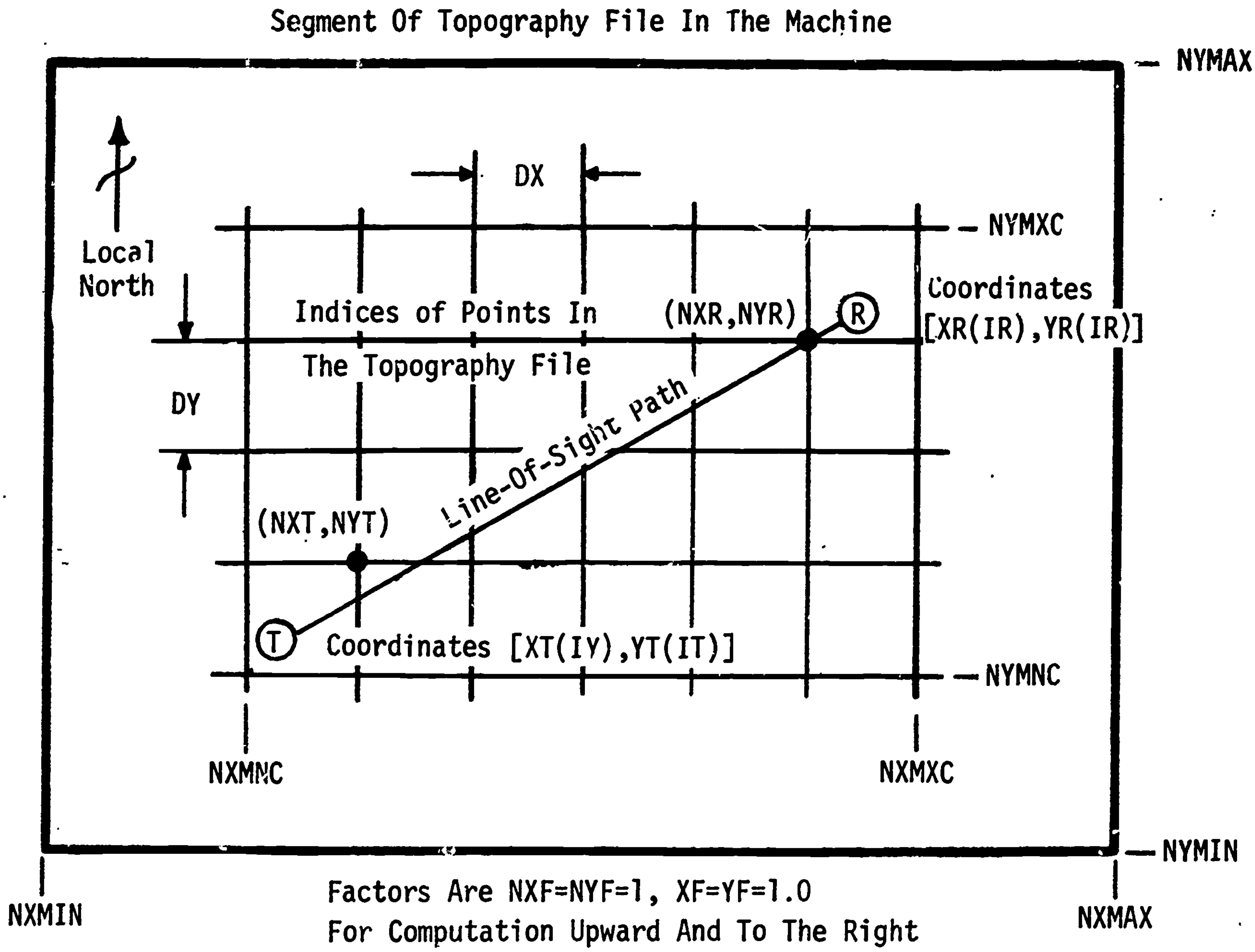
YCOT - cotangent of acute angle between line-of-sight path and topography file X-axis.

YCSC - cosecant of acute angle between line-of-sight path and topography file X-axis.

Figure 35 shows the physical relationship among variables involved in 1) initializing the topography computations and 2) checking to see that a transmitter or receiver does not lie outside the file segment currently in the machine. Following the flow diagram of figure 36, the routine first checks XDIST: does the transmitter lie to the right of the receiver? If so, the transmitter coordinate XT is used to compute NXMXC (the X index of the vertical line of file points lying next right from the transmitter position). The line-of-sight path goes to the left from the transmitter, so its reference point lies in the vertical line of points next left from the transmitter position and has index NXT=NXMXC-1. Similarly NXMNC and NXR can be computed at once.

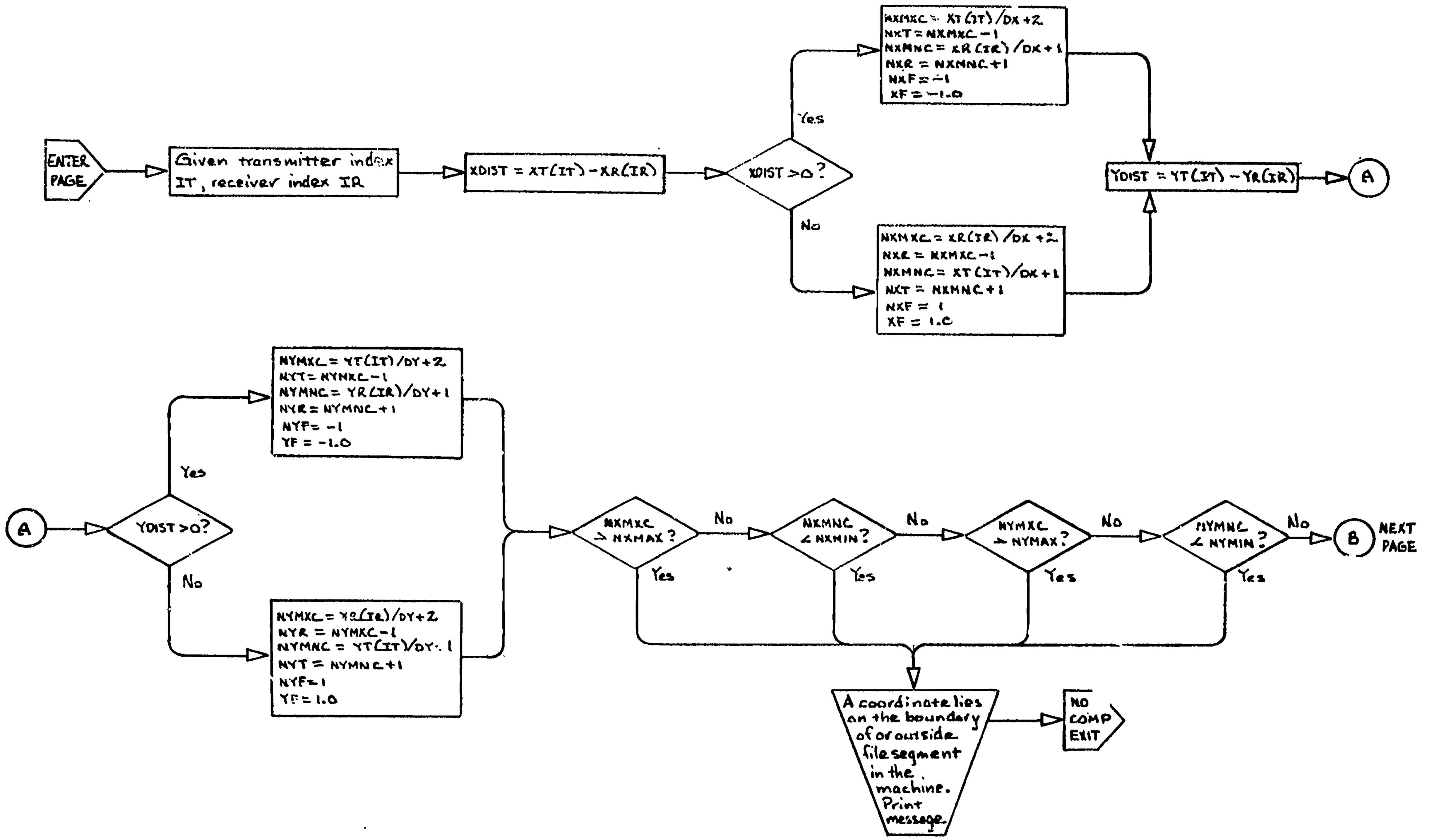
In the same box of figure 36, NXF and XF are made negative. The program logic was laid out so that the signs of all computed quantities would be correct if the receiver were above and to the right of the transmitter. The factors NXF, NYF, XF and YF have been inserted at the proper places to adjust signs of computed quantities when the receiver is below or to the left of the transmitter (or both).

Fig. 35 VARIABLES IN INITIALIZATION AND COORDINATE CHECK



Factors Are NXF=NYF=1, XF=YF=1.0
For Computation Upward And To The Right
From Transmitter To Receiver

Fig. 36 - TOPOGRAPHY FACTOR INITIALIZATION AND COORDINATE CHECK



If the transmitter does not lie to the right of the receiver, the program branches down from the XDIST test, and the positions of XT and XR in lower box computations are reversed from those in the upper box. The receiver is properly placed (to the right of the transmitter) so no sign compensation is required.

A corresponding test and resulting calculations occur for YDIST. Then a check determines that the file segment required to compute a complete terrain record is contained within the segment currently in the machine, and the routine proceeds to point B in figure 37.

As noted in 5.6, the value with indices (1,1) in the machine's array NELEV may have come from position (1+NXADJ, 1+NYADJ) in the topography file if segments of the latter are being used. In this case the X and Y indices of variables NELEV in figure 37 should be decremented by NXADJ and NYADJ respectively, to address them at the correct locations in the machine.

The terrain record is actually computed in two stages. When K=1 elevations are computed at points where the line-of-sight path crosses vertical grid lines (points 1,2 and 4 in figure 38). When K=2 elevations are computed at points where the line-of-sight path crosses horizontal grid lines (point 3 in figure 38). The process will be explained for K=1; the approach when K=2 carries over from it and should be apparent.

The routine begins by computing distances XBEG and YBEG to the vertical and horizontal (respectively) grid lines through its reference point. The line-of-sight path in all likelihood

Fig. 37 - TOPOGRAPH

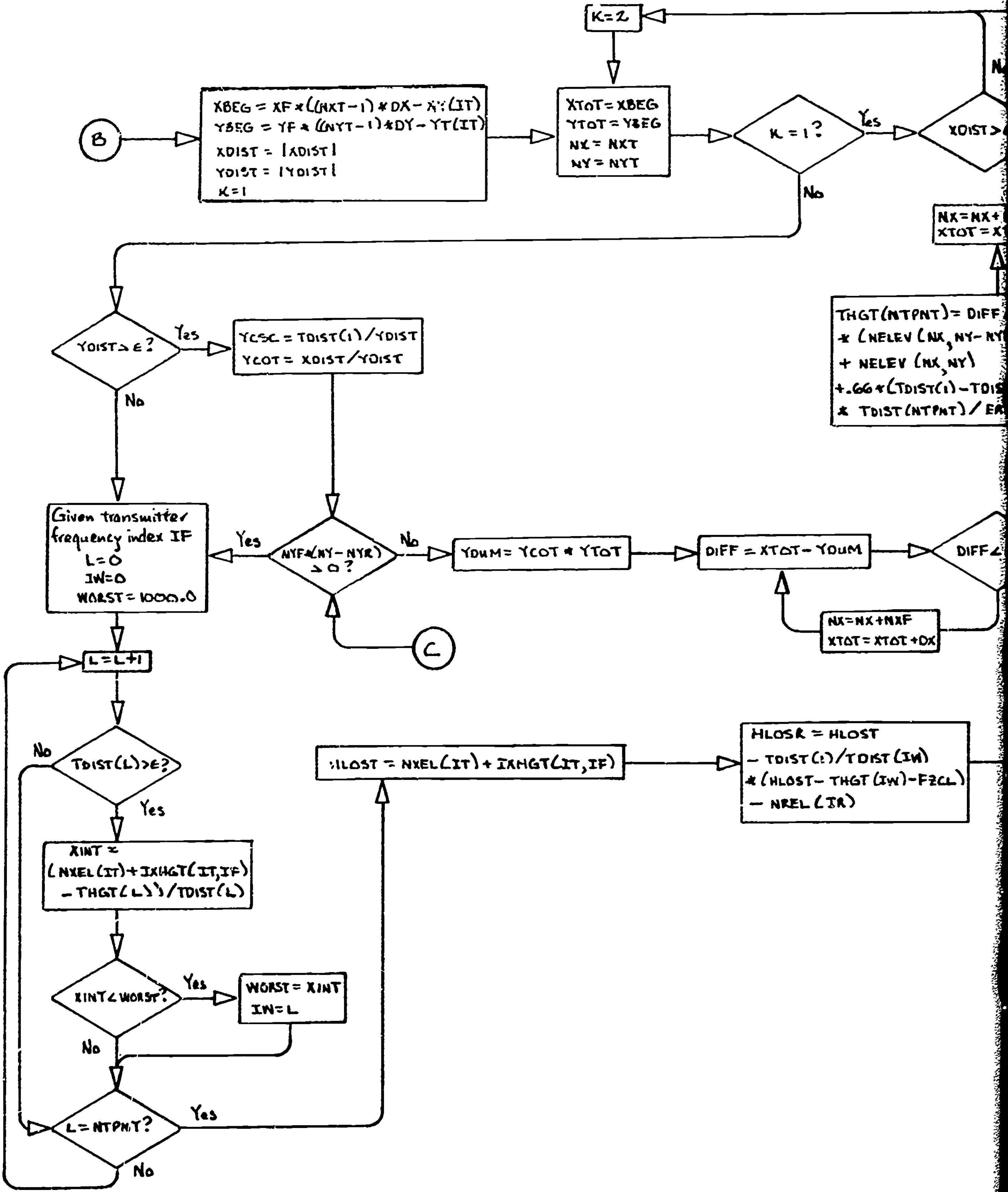
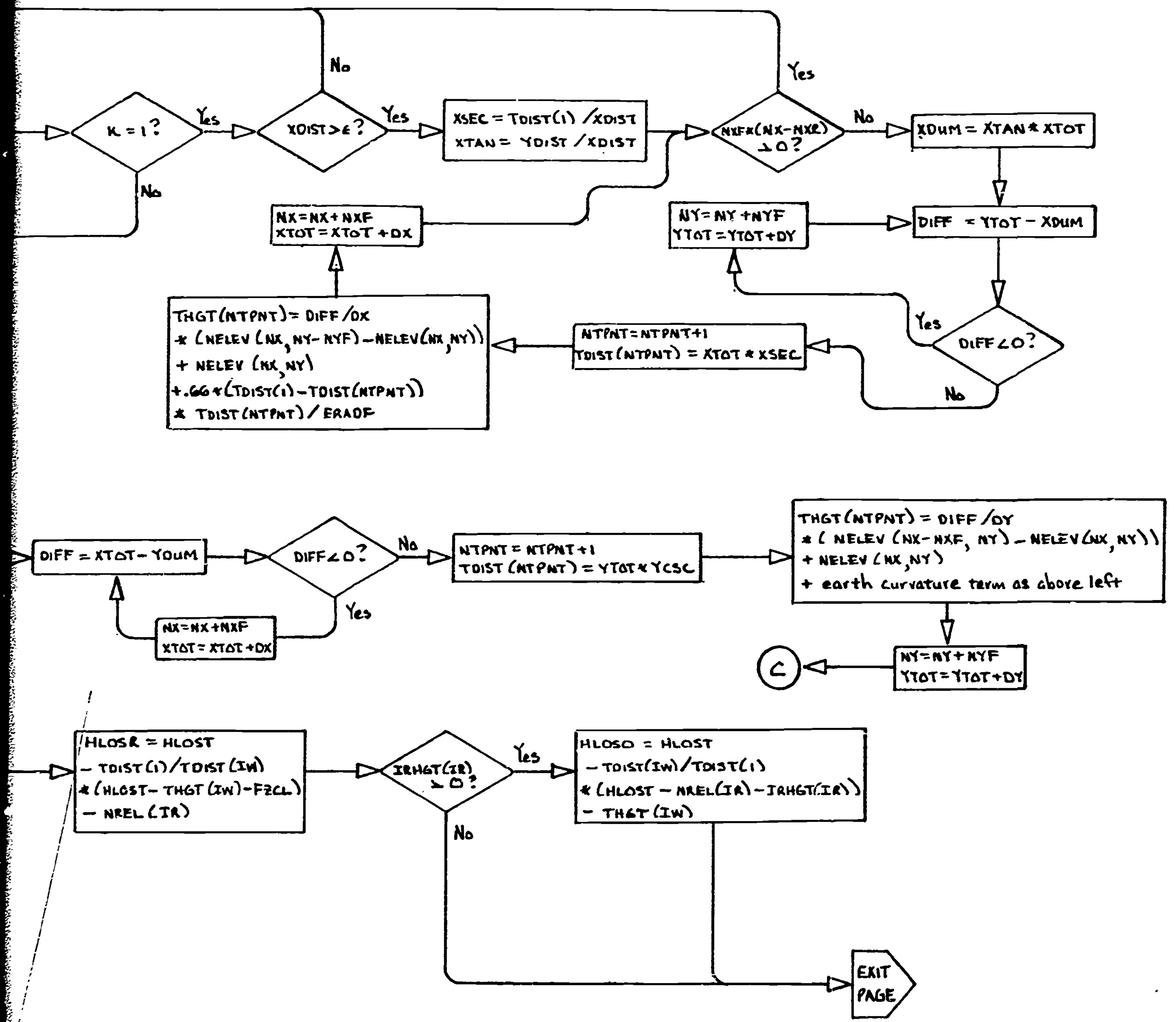


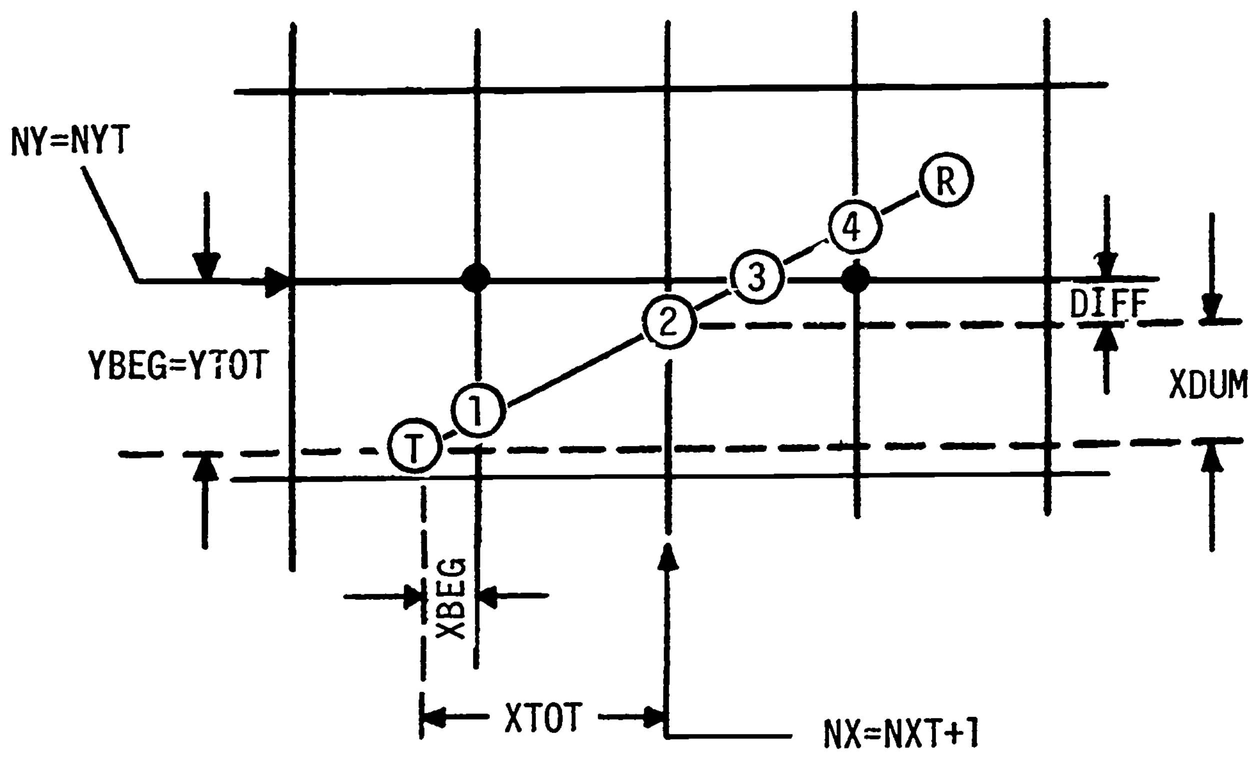
Fig. 37 - TOPOGRAPHY COMPUTATIONS



intersects the vertical line through the reference point, so it is initialized as the first possible end point. "End point" means specifically:

1) when K=1, the elevation NELEV (NX,NY) that is farther north of two points separated by distance DY on a vertical grid line; between the two points the line-of-sight path intersects that vertical grid line.

Fig. 38 VARIABLES IN COMPUTATION OF TERRAIN RECORD



Variables Shown For Computation Of Elevation At ②

Order Of Computations Is ① , ② , ④ , ③ .

2) when K=2, the elevation NELEV (NX,NY) that is "farther to the right" of two points separated by distance DX in a horizontal grid line; between the two points the line-of-sight path intersects that horizontal grid line.

In operating when K=1 the routine uses two facts. First, the line-of-sight path crosses every vertical line from index NXT through index NXR. Second, each succeeding crossing as the path moves to the right is farther north than its predecessor. After initialization the secant XSEC and tangent XTAN are computed for the angle between the line-of-sight path and the topography file X-axis. Then the difference NX-NXR is tested for positive. If this difference is positive immediately, the transmitter and receiver both lie between adjacent vertical lines; therefore no verticalline is crossed by the path. Otherwise, the vertical line with index NX is crossed at distance XDUM above or north of the transmitter position. The point NELEV (NX,NY) is at distance YTOT north of the transmitter position on this line.

DIFF is zero or positive, indices (NX,NY) mark an endpoint. A crossing occurs at distance TDIST from the transmitter, DIFF south of NELEV (NX,NY). The elevation at the intersection is found by interpolating between the end point and NELEV (NX, NY-1) and adding a correction factor for earth curvature. Notice that if DIFF is negative, the program increments index NY by one. The point with incremented NY is DY farther north on the vertical line; the DIFF test is repeated to see if it is an end point.

When an intersection with a vertical grid line has been found and interpolation performed, the routine moves to the next vertical line by incrementing NX and increasing horizontal distance XTOT from the transmitter position. In the situation of figure 38, the transmitter reference point (the left heavy dot) is an end point, so the elevation at 1 is computed at once. When NX is incremented for the first time, the computations are at the stage shown in the figure. The elevation at the midpoint of the horizontal line connecting reference points is the endpoint at this stage.

The difference NX-NXR is positive just after the intersection with the vertical line having index NXR has been processed. This is the last vertical line crossed before the line-of-sight path reaches the receiver, so computations with K=1 cease.

The correction factor added to the interpolated elevation value at an intersection is shown in figure 39. It is a parabolic approximation to the curvature of the earth, adjusted by ERADF (defined in 3.0). In this application

D = TDIST (1), the distance from transmitter to receiver.

X = TDIST (NTPNT,) the distance from transmitter at which an intersection occurs.

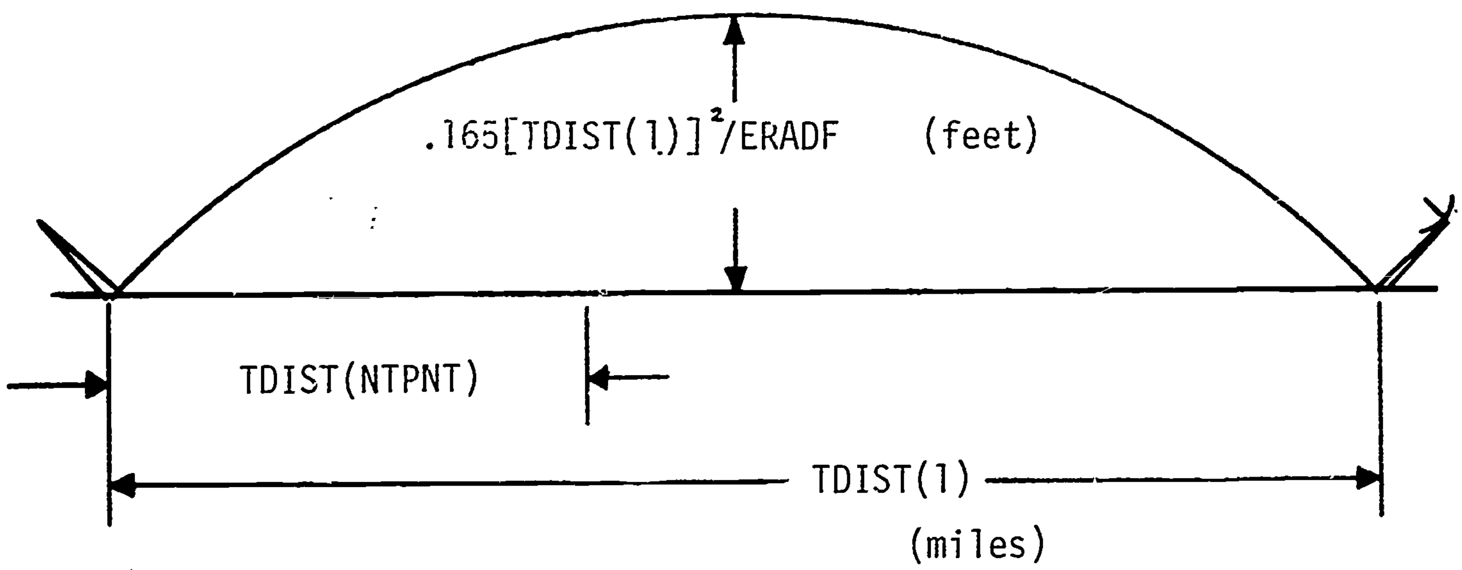
RF = ERADF

In figure 37 a test should be added "in two places to" insure that the index NTPNT does not exceed the storage alloted for the terrain record arrays TDIST and THGT. If storage will be exceeded, the routine should terminate ter-

rain record computations and proceed immediately to the worst test.

After stages K=1 and K=2 are complete, the program computes XINT (defined above) for each point in the terrain record and finds the point with index IW that has the smallest such value, WORST. Its combination of distance TDIST from the transmitter and elevation THGT make IW the point in the terrain record at which Fresnel zone clearance FZCL must be assured.

Fig. 39 TERM IN ELEVATION COMPUTATION TO CORRECT FOR EARTH CURVATURE AND ATMOSPHERIC REFRACTION



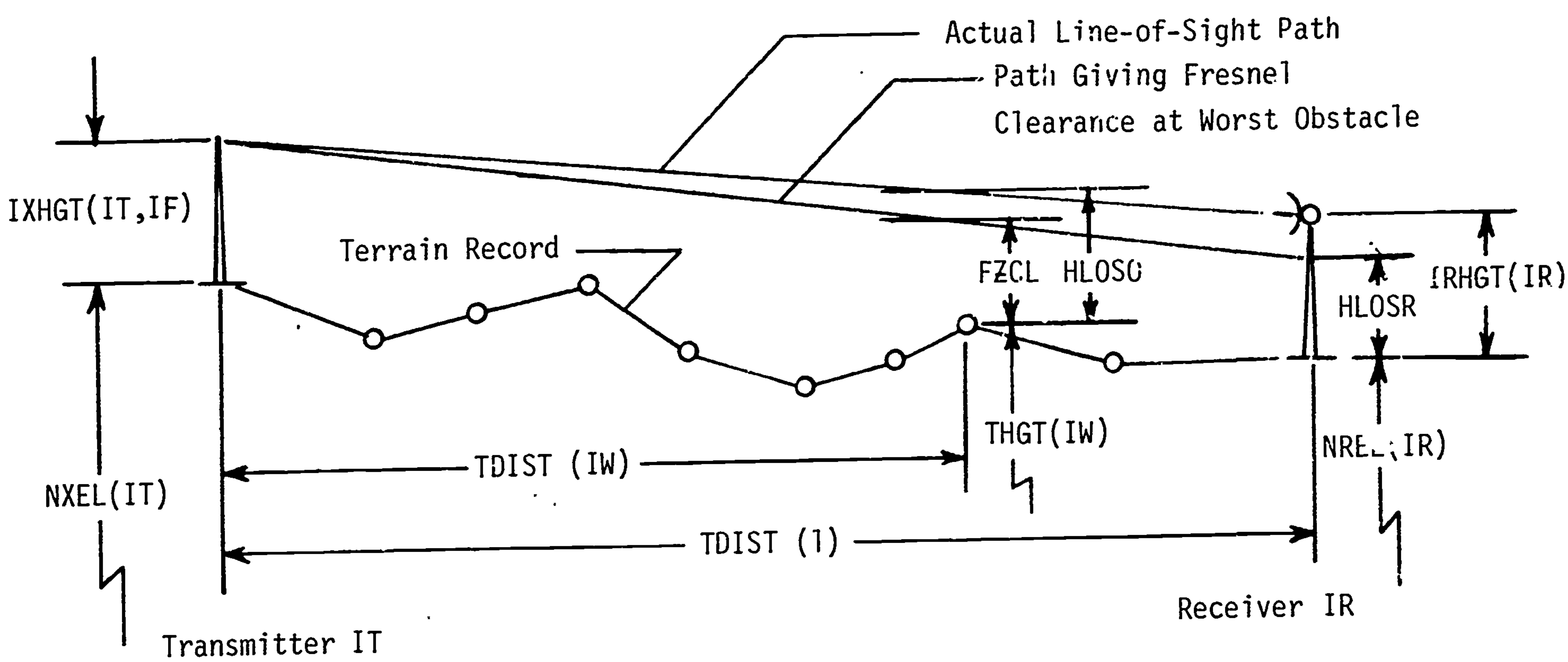
Correction = $.66(DX-X^2)$ /RF (feet)

Where D= total distance between points (miles)

X= distance at which correction is computed (miles)

RF= ratio of equivalent to actual earth radius

Fig. 40 VARIABLES IN COMPUTATION OF LOS CLEARANCE AT WORST OBSTACLE IN TERRAIN RECORD



In figure 40 variables in the remaining computations are represented. At the transmitter the line-of-sight path elevation HLOST is at the top of the antenna for the frequency IF involved, the sum NXEL and IXHGT of variables at the left of the figure. To provide Fresnel zone clearance FZCL at point IW the receiver antenna height must be at least HLOSR, computed by using a similar triangle relationship and subtracting NREL. If receiver antenna height is specified, the actual path clearance HLOSO at point IW is computed by using a similar triangle relationship and substracting THGT.

Notice in figure 40 that the worst point IW is not necessarily the point with greatest elevation THGT; it depends

on distance TDISTjas well. In this program the desired Fresnel zone clearance has been assumed as constant (FZCL, defined in 3.0). Therefore, it does not affect IW. However, the accepted formula for Fresnel zone clearance at a point L in the terrain record (in terms of program variables) is:

$$FZCL(L) = .6x5280x\sqrt{\frac{CLGHT/ITXFR(IT,IF)xTDIST(L)x(TDIST(1)-TDIST(L)}{TDIST(1)}}\ \text{feet}$$

In this case XINT should be redefined as (HLOST-THGT(L)-FZCL(L)/ TDIST(L) in identifying IW. Since IW is found by including FZCL(IW) in the revised definition of XINT, then

HLOSR = HLOST - WORST x TDIST(1) - NREL(IR)

For the computation involving HLOSO a more extensive change might be desirable. Suppose the actual receiver antenna height IRHGT is such that the path clearance at IW is less than FZCL(IW).

Then IW is not necessarily the point IO in the terrain record at which the largest fraction of FZCL(IO is obstructed.

Define:

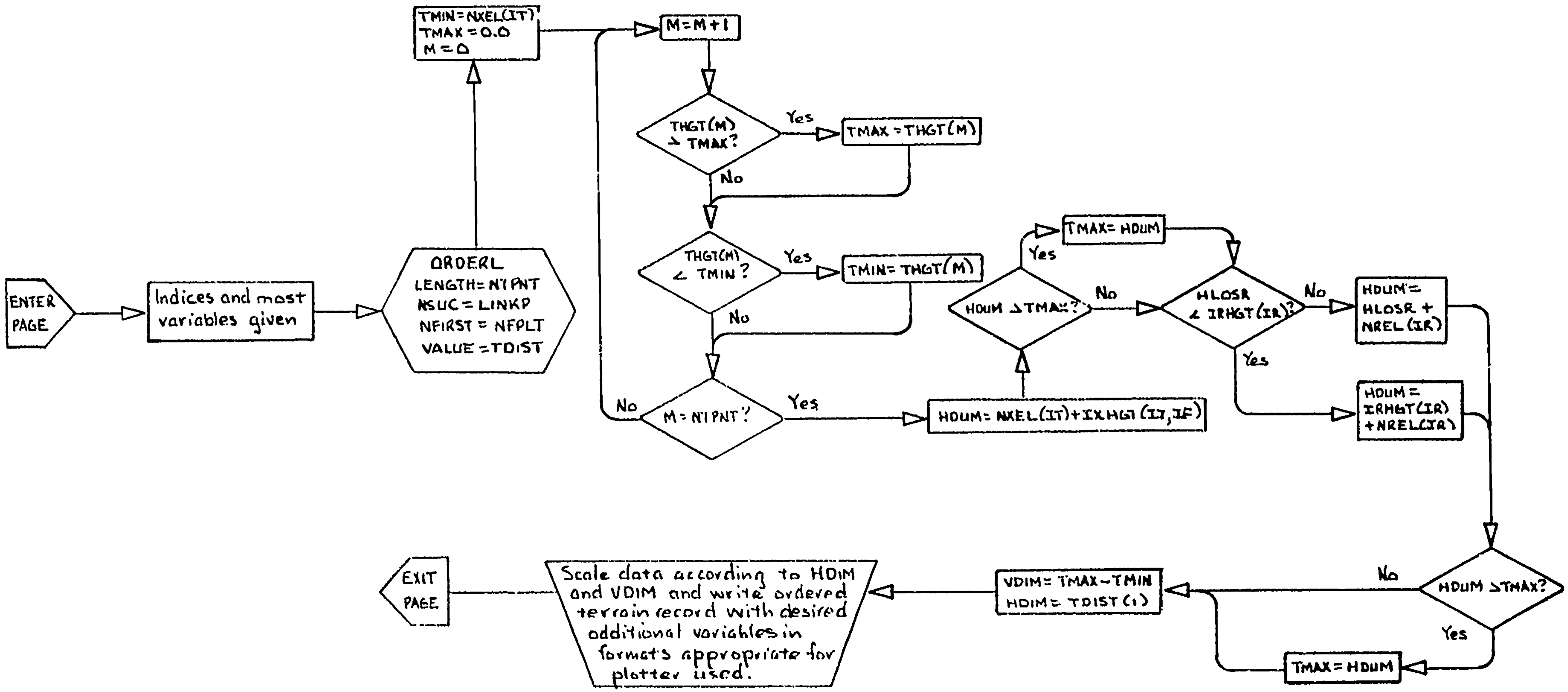
HLO(L)=HLOSO computed for each point L in the terrain record

Then IO is the point in the terrain record at which HLO(L)/ FZCL(L) is a minimum.

6.5 Plotting Computations

Information generated in the topography computations can be readily organized and written on tape for later input to a plotter. The exact formats required depend on what plotter is used. Figure 41 described in general what might be done with the data. Variables are defined on the next page.

Fig. 41 - PLOTTING COMPUTATIONS



Definitions:

HDIM - horizontal range of numbers in data, miles.

HDUM - highest elevation at receiver and transmitter sites, feet

LINKP - index of successor to a point in the ordered terrain record.

NFPLT - first point in ordered terrain record.

TMAX - maximum elevation in data, feet.

TMIN - minimum elevation in data, feet.

VDIM - vertical range of numbers in data, feet.

The terrain record is ordered low on distance from the transmitter. Then the minimum and maximum elevations TMIN and TMAX, respectively, are found by testing the terrain record and other quantities and used to compute VDIM. HDIM is already in the data. With the latter figures the data can be scaled and written for plotting.

6.6 Obstacle Interference Computations

If an obstacle IO may interfere with the line-of-sight path between transmitter IT and receiver IR, the computations shown in figure 42 are made. Physical arrangement of the variables is in figure 43. Major variables introduced at this point are defined below. Distance variables are in miles or miles 2.

Definitions:

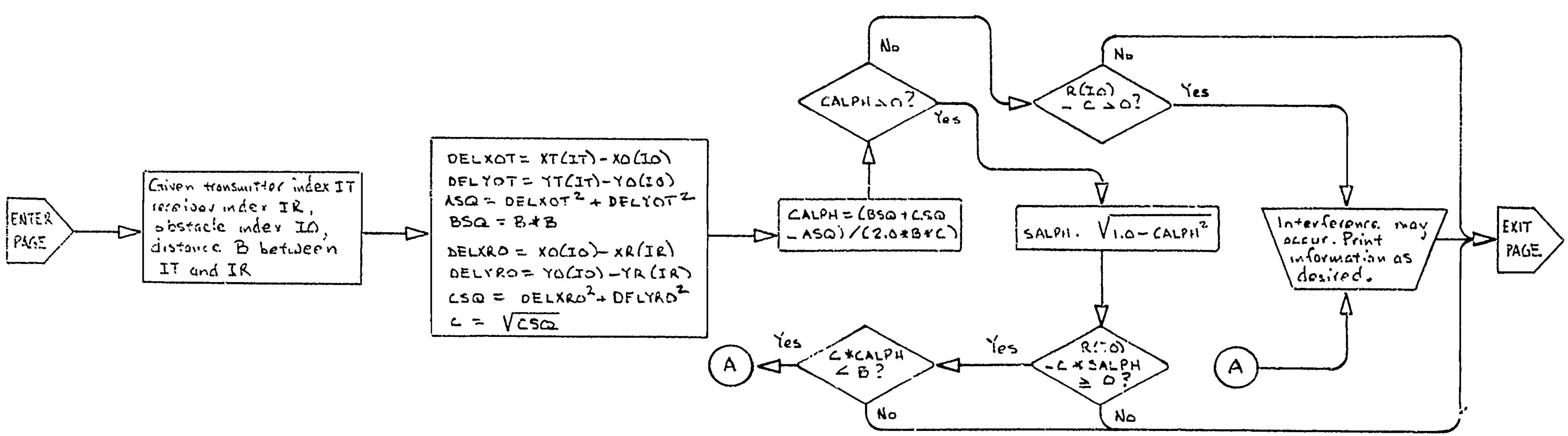
ASQ - square of distance between transmitter and obstacle.

B - distance between transmitter and receiver.

BSQ - square of distance between transmitter and receiver.

C - distance between receiver and obstacle.

Fig. 42 - OBSTACLE INTERFERENCE COMPUTATIONS



CSQ - square of distance between receiver and obstacle.

CALPH - cosine of angle ALPH between B and C.

SALPH - sine of angle AlPH between B and C.

First the distances and/or their squares among IT, IR ana IO are computed. Then the law of cosines is applied to find CALPH. If CALPH is not positive, then ALPH is obtuse and the obstacle is behind the receiver with respect to the line-of-sight path. Interference might occur due to signal reflection if the obstacle's effective radius R exceeds distance C from the receiver.

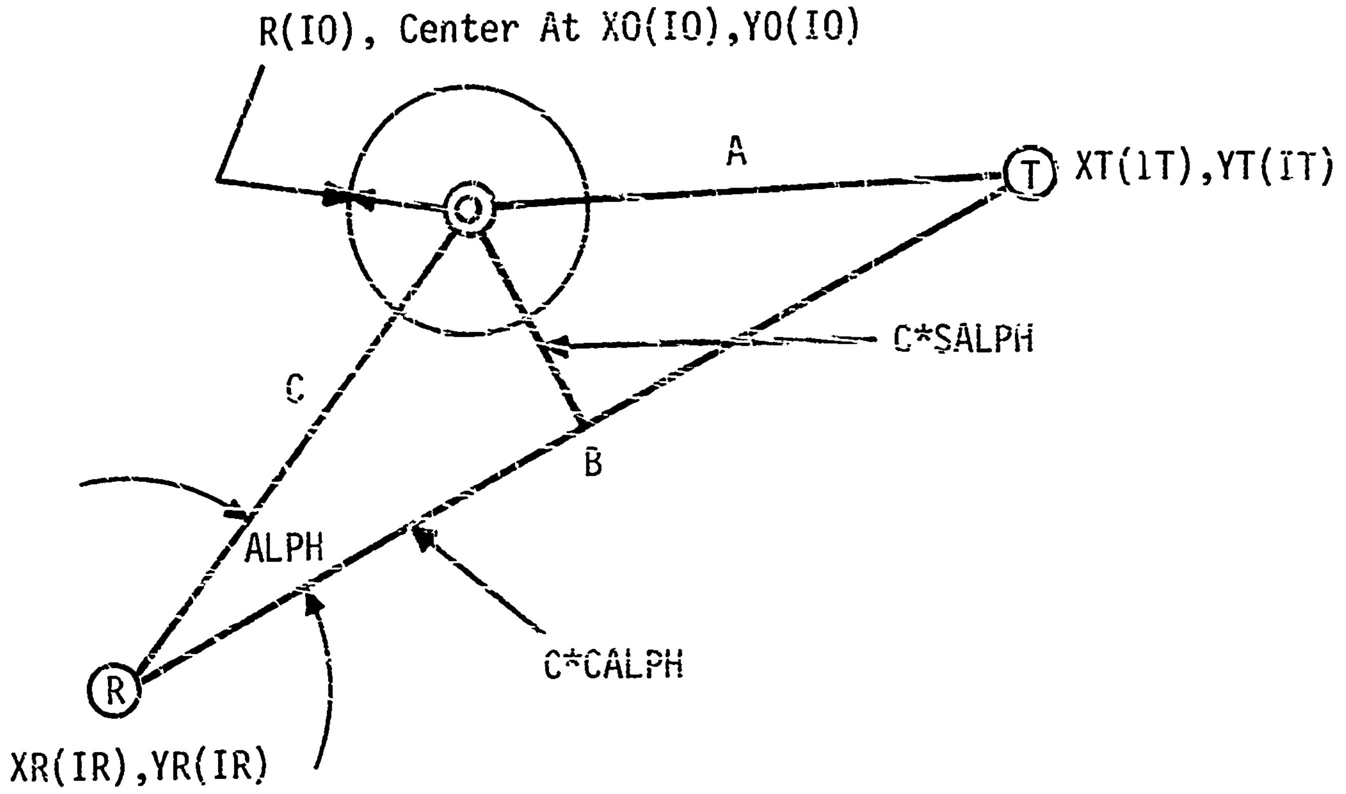
If CALPH is positive, the perpendicular distance C x SALPH from the obstacle to the line-of-sight path is compared with R. When it is less than R and the intersection of C x SALPH with B takes place between IT and IR, interference may occur. In figure 42 the first of these two latter test fails - no inferference might occur unless R were somewhat more than twice the magnitude shown.

6.7 Interfering Transmitter Compuations

The power of an interfering signal at a receiver is a product of the same factors explained in 6.3 for power of the desired signal, with the following exceptions.

1. In the path loss equation, the frequency ITXFR of the interfering signal replaces the receiver's desired frequency, IRFR.
2. The receiver antenna gain GDUM replaces Gr. GDUM depends on whether the polarizations NXPOL of the interfering and NRPOL of the desired signal are equal or opposite.
3. An additional factor W is included in the product to account for difference in frequency between signals ITXFR and IRFR.

Fig. 43 VARIABLES IN OBSTACLE INTERFERENCE COMPUTATIONS



The product of terms in 6.3 altered as noted above is the interference power at the receiver, TI. When a particular interfering transmitter location is treated as shown in figure 44, only W, ITXFR, GDUM and XPWR change as each of its frequencies is examined. The other factors in the product TI are combined as FACT when the computations begin, and FACT remains constant throughout subsequent calculations.

Variables in figure 44 that require definition are listed below. Additional pertinent definitions are in 6.3.

Definitions:

BI - bearing from local north to interfering transmitter at receiver, radians.

BRI - relative bearing from receiver antenna 0^o line to interfering transmitter at receiver, radians.

DIFF - difference between computed signal TI and a stored worst signal TIW, watts.

DIFM - maximum positive DIFF encountered in searching array TIW.

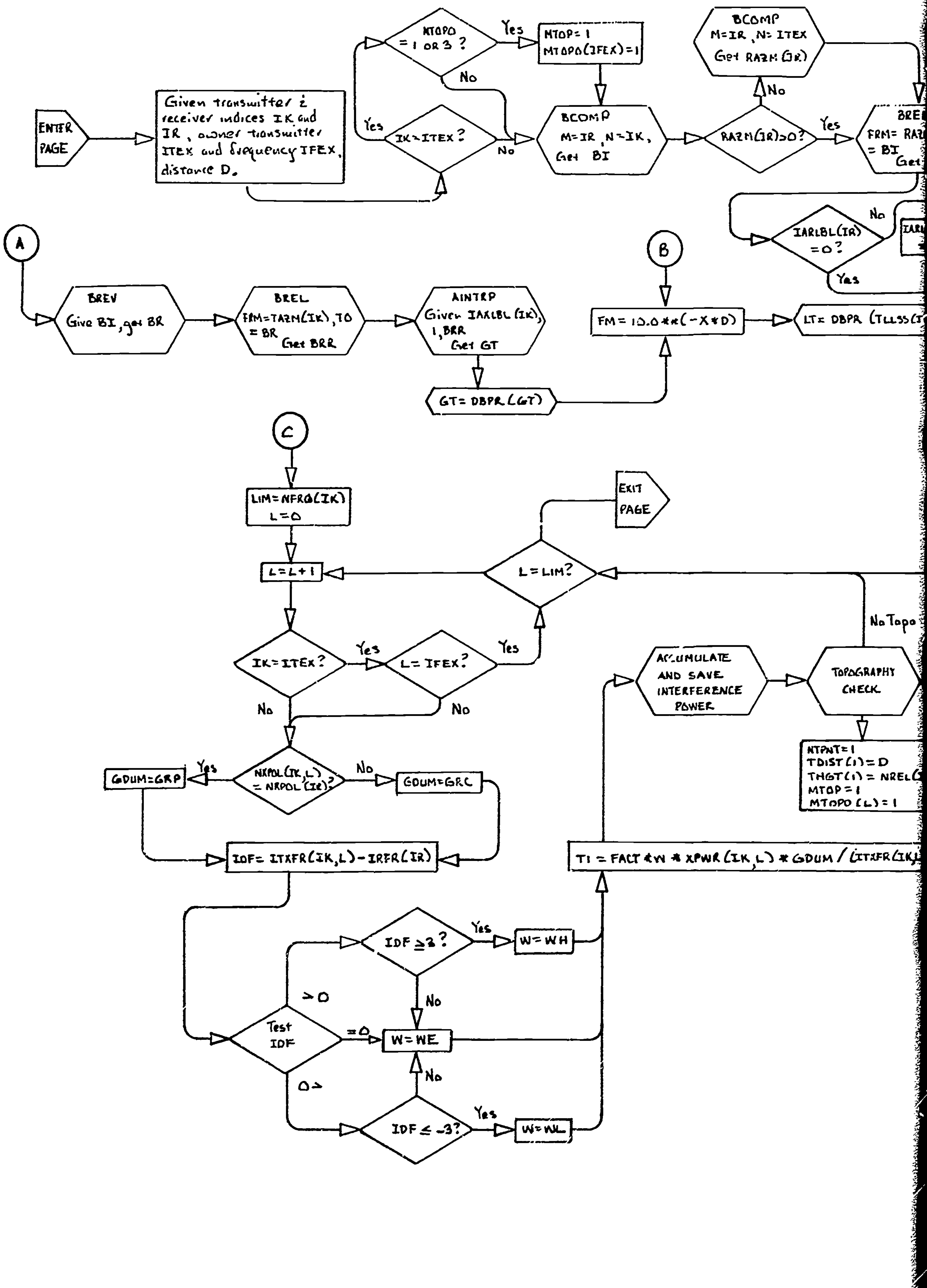
FACT - product of all factors in TI that do not change with transmitter frequency.

GDUM - receiver antenna gain for interfering signal in direction of interfering transmitter, expressed as a ratio.

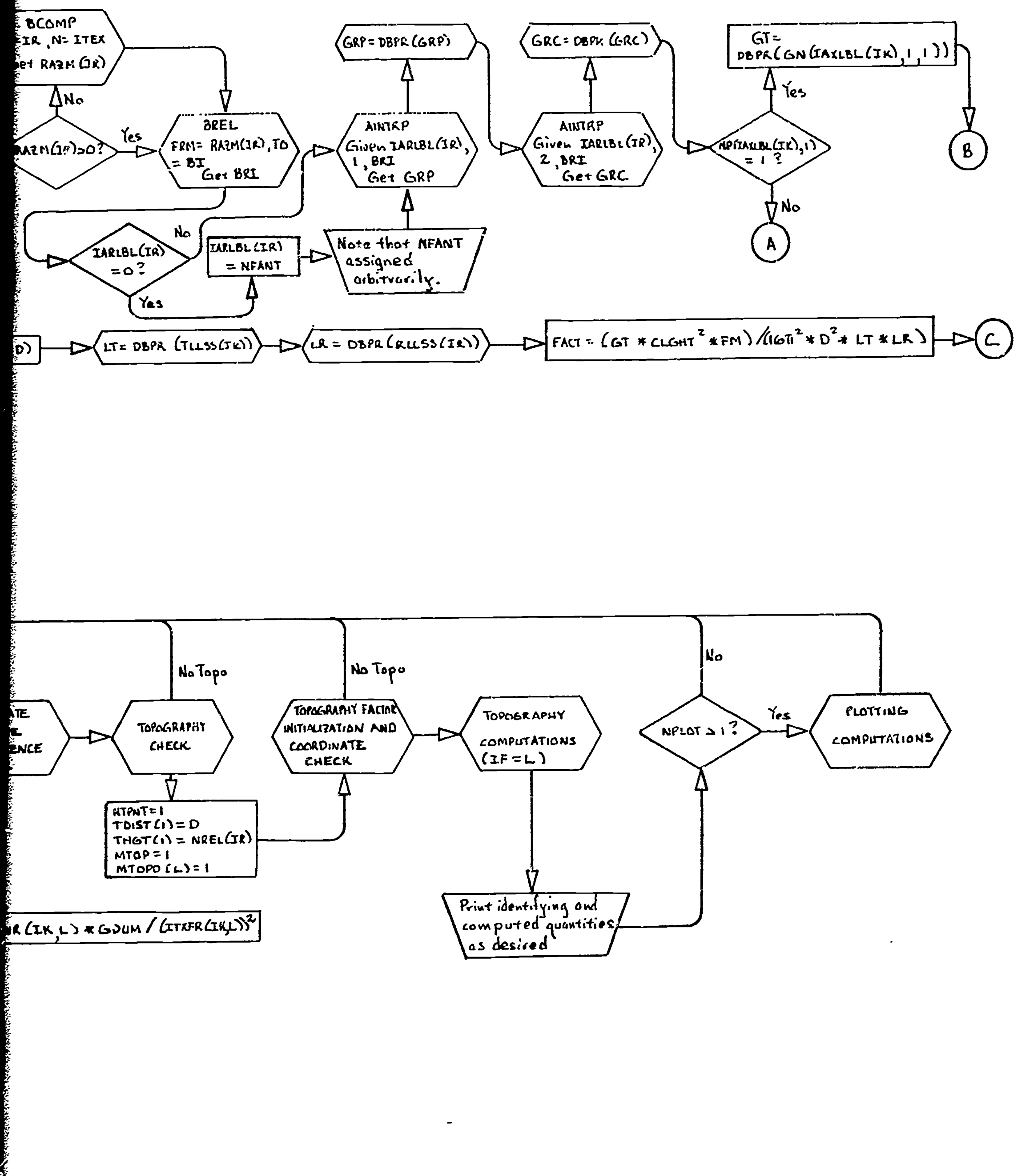
GRC - cross polarization gain of receiver antenna in direction of interfering transmitter, expressed as a ratio.

GRP -	primary polarization gain of receiver antenna in direction of interfering transmitter, expressed as a ratio.
IDF -	difference between interfering and desired frequencies, megacycles.
IFEX -	index of desired frequency at owning transmitter.
IKW -	index of a source transmitter for one of 3 worst interfering signals.
ITEX -	index of owning transmitter.
LW -	array for frequency indices of three worst interference sources.
MDIFM -	index of member of array TIW for which DIFM was computed.
MTOP -	parameter that is 1 if topography computations have been made for an antenna at interfering transmitter of current interest for receiver, 0 otherwise.
MTOPO -	array showing which antennas were involved in previous topography computations at interfering transmitter of current interest for receiver.
NWST -	number of entries in worst interfering signal arrays.
TI -	interference power at the receiver, watts.
TITOT	total interference power at receiver from all transmitters, watts.
TIW -	array for interference power from three worst interference sources.
W -	weighting factor for frequency differences IDF.
WE -	value of weighting factor[=DBPR (12.)]if IDF $<$ 3
WH -	value of weighting factor[=DBPR (-57.)]if IDF $>$ 3
WL -	value of weighting factor[=DBPR (-60.)]if IDF $<$ -3

Fig. 44 - INTERFERING TRANSMITTER COMPU



TRANSMITTER COMPUTATIONS



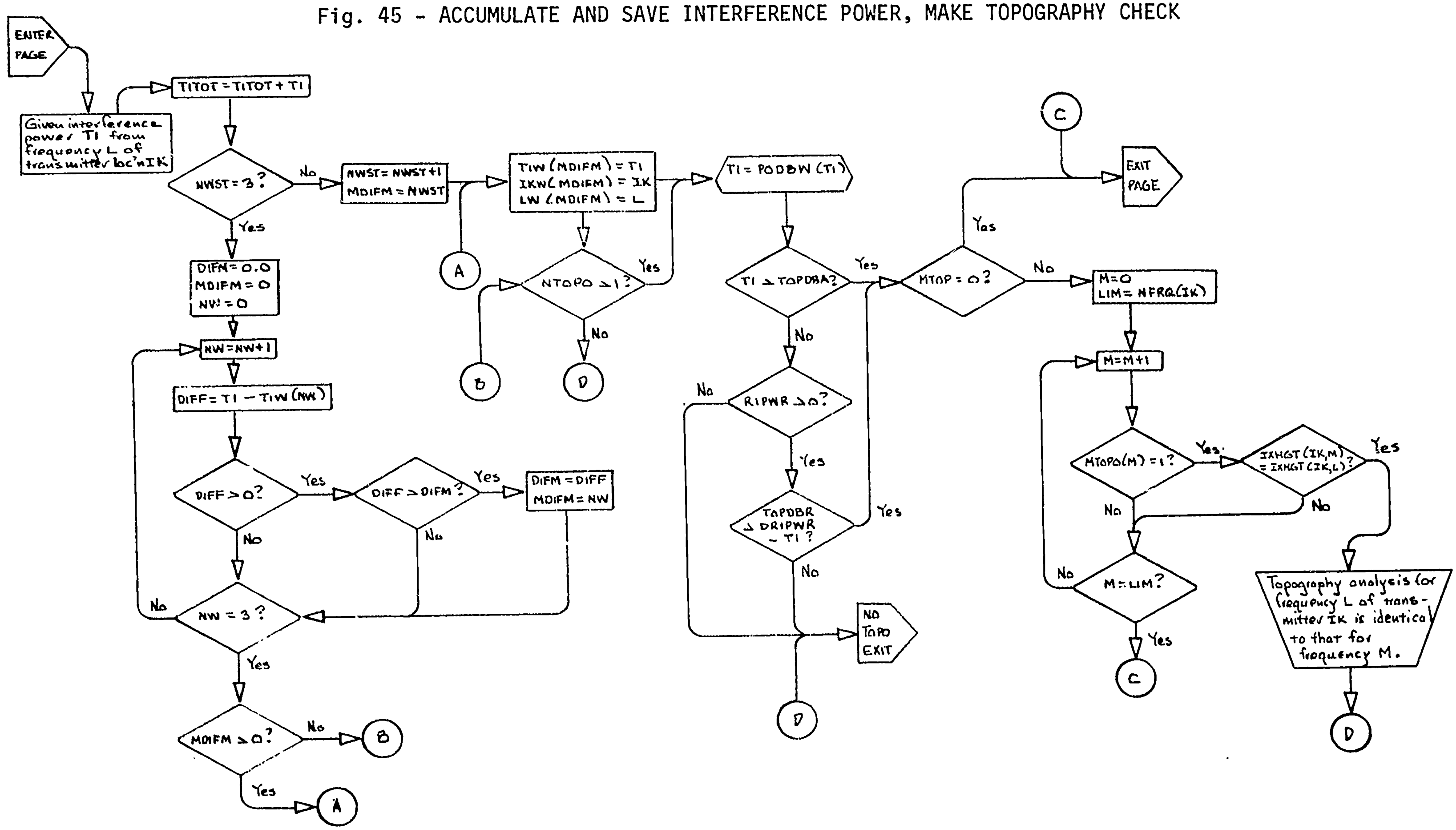
In the routine of figure 44 the transmitter IK, receiver IR and distance D between are given as well as the receiver's owning transmitter ITEX and assigned frequency IFEX. The transmitter location ITEX broadcasting the desired signal IFEX to a receiver may also act as an interference source in broadcasting other signals, and it will be processed in these computations. If topography computations were requested earlier for this transmitter (NTOPO=1 or 3), this version of the program will have made the computations successfully. The purpose of MTOP and array MTOPO is to prevent the repetition of topography computations at the same location for antennas of the same height (see figure 45 and discussion below), so MTOP and MTOPO (IFEX) are marked.

When the file read scheme in 5.6.3 is used, the above redundancy check must be taken out of the program. The position suggested in 5.6.3 for the read scheme lies above the MTOP check in figure 45. If the program depends on reading at that point, the redundancy check described in the above paragraph would indicate falsely that the proper file segment for computations was in the machine.

The bearing BI to the interfering transmitter is computed next. If the receiver antenna azimuth RAZM is zero, it is computed as the bearing to the receiver's owning transmitter ITEX. Then the relative bearing BRI is figured for interpolation with the antenna tables.

If at this point a receiver antenna label IARLBL is blank, an error has probably been made. The analyst may have wanted the program to pick an antenna but it bypassed the routine which does this (6.3). At any rate a check in 5.3 has insured that the

Fig. 45 - ACCUMULATE AND SAVE INTERFERENCE POWER, MAKE TOPOGRAPHY CHECK



ordered antenna list is not empty, and NFANT is assigned arbitrarily to the receiver.

Value BRI is used to take from tables the antenna's primary (GRP) and cross (GRC) polarization gains in the direction of the interfering transmitter. The transmitter antenna gain GT is obtained directly or by interpolation. Then in order the quantities FM, LT, LR and FACT are calculated.

From point C onward the same set of calculations is repeated for each frequency L broadcast from the transmitter. If the transmitter IK is the owner ITEX and L is its assigned frequency IFEX, no interference power TI is computed. Otherwise the proper receiver antenna gain GDUM is picked by comparison of interfering and desired signal polarizations. If the polarizations are opposite GDUM is the receiver antenna's cross polarization gain GRC. If the polarizations are the same, it's primary polarization GRP is GDUM.

Finally, the difference in megacycles between interfering and desired frequencies is used to determine the proper value of weighting factor W, and interference power TI is calculated for frequency L.

The next two functions in the routine are flowcharted in figure 45. TI is added to the total interfering signal TITOT arriving at the receiver. Then a check is made to determine whether this single signal TI is greater than one (or more) of the three single signals previously picked as the worst affecting the receiver. If the answer is yes, the index MDIFM is identified for the previously picked signal TIW (in the list of 3) that TI

exceeds by the greatest amount DIFM. The magnitude, transmitter and frequency index for the current signal then replace corresponding characteristics for MDIFM in the list.

The check to see whether topography computations should be performed for frequency L of transmitter IK is made in several steps. First the switch NTOPO must request the computations. Then the interference power TI must satisfy either of the two criteria TOPDBA or TOPDBR specified in the controls (3.0). If TI is above absolute interference limit TOPDBA in dbm, the routine proceeds. When this test fails and power RIPWR for the desired signal has been computed (6.3), the program will also proceed if the signal to interference ratio DRIPWR-TI is less than TOPDBR. Finally, the program insures that topography computations already made for this transmitter-receiver pair did not involve a transmitter antenna M with the same height IXHGT as that for frequency L.

The routine then puts the receiver distance and elevation in the first terrain record point, marks the antenna under consideration and performs topography computations (6.4).

It performs plotting computations if desired (6.5) and returns to see if any other frequencies remain to be processed at interfering transmitter IK. When none remain the program exits from the routine.

7.0 Control Processes

The sections of the program that have been discussed to this point are related to one another by some connective tissue. Major and minor processes embedded in this connective tissue

are discussed in the following sections. The complete framework, the program itself, is examined in 7.4.

7.1 Sequence of Computations

Selection within the program of the computations to be performed depends on evaluation of the four parameters NCOMP, NTOPO, NPLOT and NOBST defined in 3.0. Settings of these parameters are changed at several places in the program using the processes shown in figure 46.

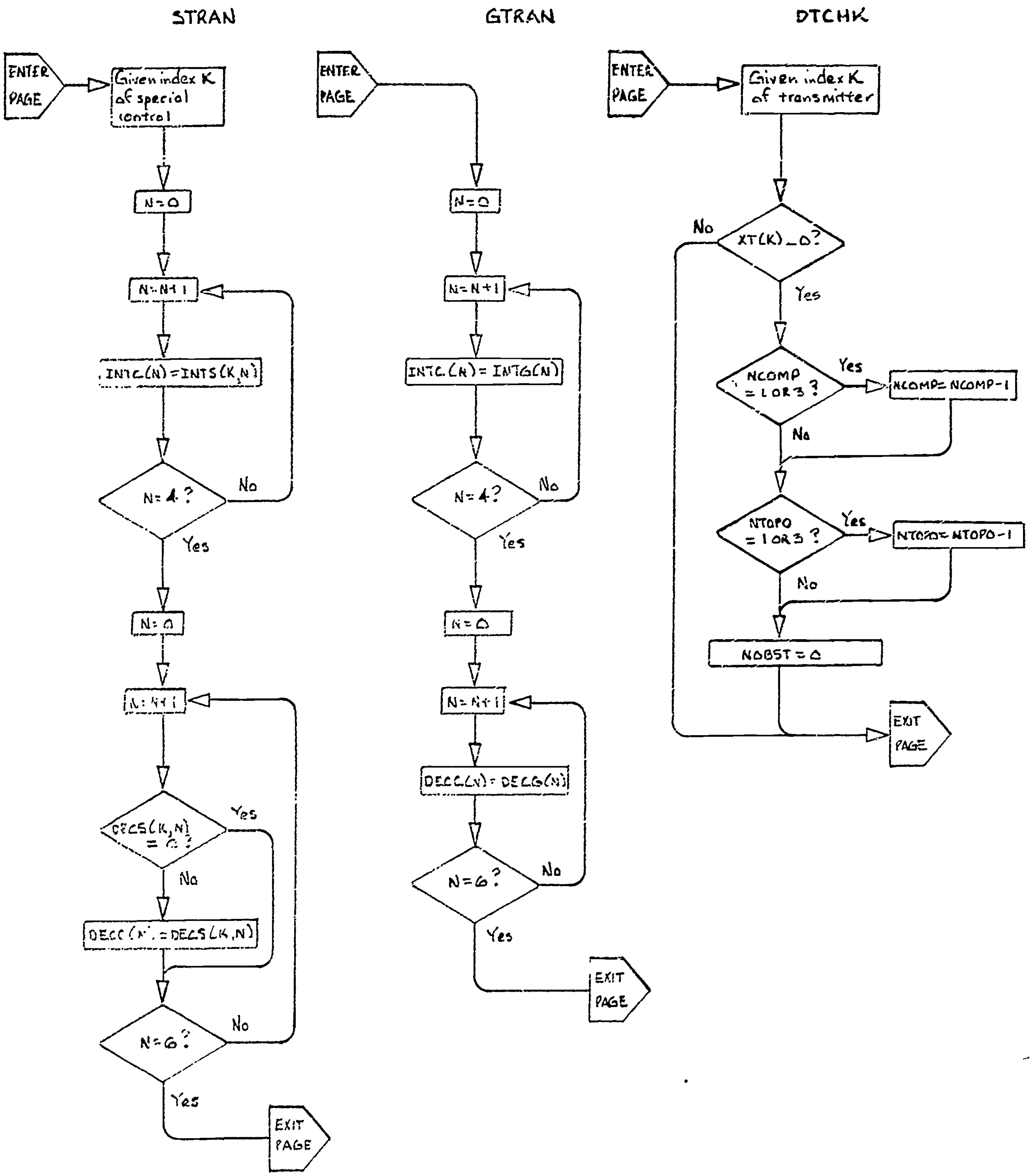
Process STRAN honors a special control request with index K; the request may pertain to a receiver or to a receiver group owned by a transmitter.

The process transfers values of integer special control variables INTS (K,L) L=1 through 4, to corresponding variables INTC (L) (equivalent to the parameters mentioned in the first paragraph). It then transfers any nonzero decimal variables DECS (k,L), L=1 through 6, to corresponding variables DECC (L) (equivalent as shown in figure 1, 3.0).

Process GTRAN establishes or re-establishes in arrays INTC and DECC the four general integer controls from INTG and six general controls DECG that may change by special request (STRAN).

Process DTCHK is a safety check to resolve any control conflicts that may inadvertently have been introduced through the presence of dummy transmitters (see 5.3). When the owning transmitter for a receiver group is a dummy, it has no X card and therefore no actual coordinates. Thus computations for receiver signal and noise power, owner transmitter topography and obstacle

Fig. 46 - PROCESSES INVOLVING CONTROL PARAMETERS



interference cannot be made. Appropriate messages could be included in DTCHK noting the nature of adjustments it makes in the parameters.

7.2 Candidate Obstacle Selection

Here the results of 5.7 are put to use. Figure 47 is a flowchart of the selection process and figure 48 shows variables involved. Several variables are defined in 5.7, and others are listed below.

Definitions:

NCH - number of sections to advance or retreat in seeking starting section of list.

NDIV - index of section currently being tested.

NPICK - section of list at which search should begin

OMAX - maximum unordered coordinate of rectangle within which candidate obstacles lie.

OMIN - minimum unordered coordinate of rectangle within which candidate obstacles lie.

ORDMAX - maximum ordered coordinate of rectangle within which candidate obstacles lie.

ORDMIN - minimum ordered coordinate of rectangle within which candidate obstacles lie.

In figure 47 the interval ORDMIN-ORDMAX that will control the list search is first defined using the transmitter and receiver coordinates TOORD and ROORD, respectively, that correspond to the ordering coordinate OORD for the obstacle list. Since RMAX is the largest effective radius among obstacles, no obstacles with OORD outside the interval can effect the line-of-sight path.

Fig. 47 - CANDIDATE OBSTACLE SELECTION

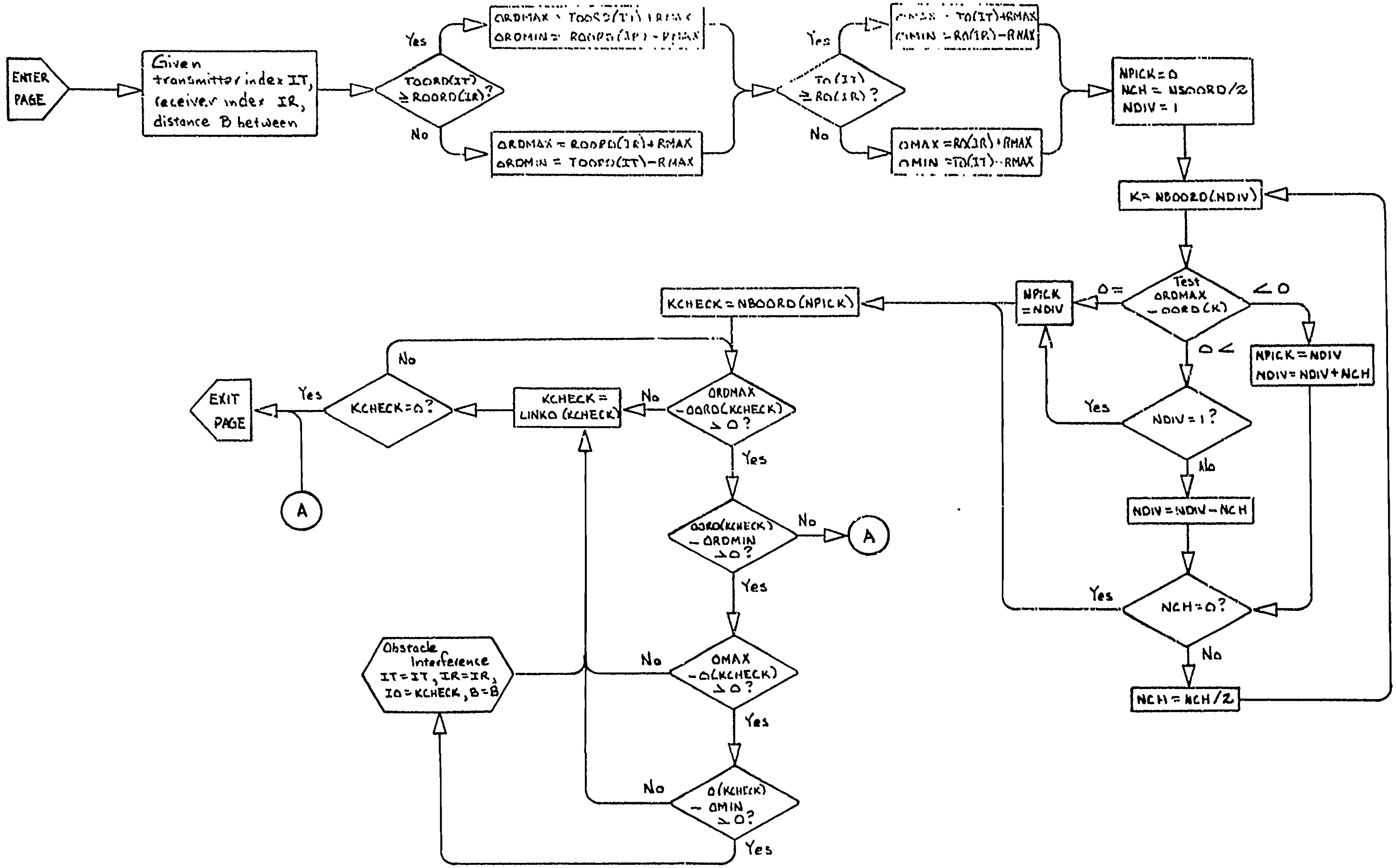
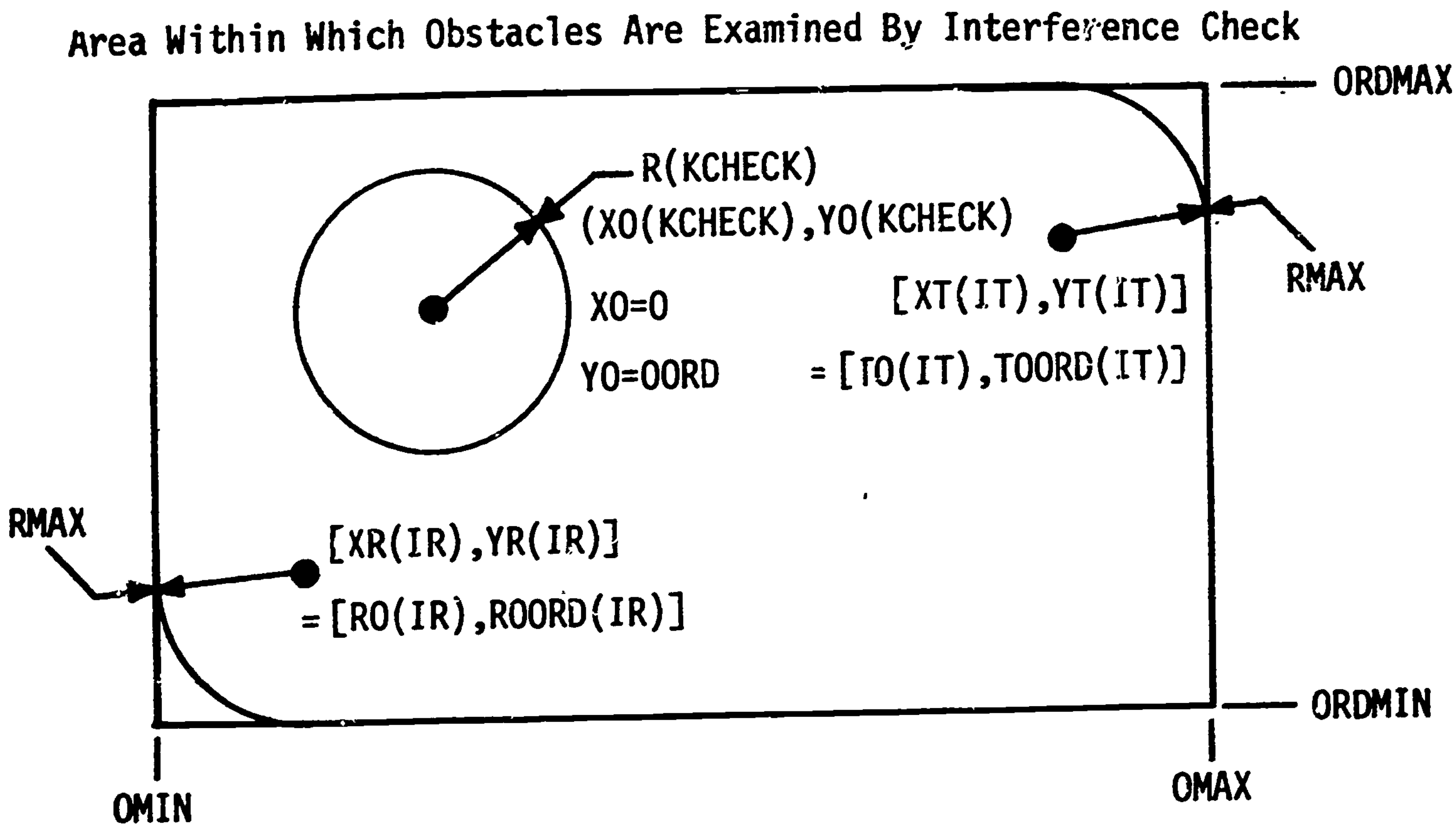


Fig. 48 VARIABLES IN CANDIDATE OBSTACLE SELECTION



In This Example Obstacles Are Ordered On Their Y Dimension

Definition of the secondary interval OMIN-OMAX completes the description of the rectangle within which obstacles must lie to be checked. The reason for use of RMAX is as above.

Next a search is made to find the section NPICK farthest down the list whose leading member NBOORD has ordering coordinate OORD greater than ORDMAX. This search takes at most half as many tests on leading members of sections as there are sections NSOORD in the list. If the leading member of the first section has OORD less than or equal to ORDMAX, NPICK is the first section.

The routine then begins testing each list member KCHECK beginning with NBOORD (NPICK). Remember that the list is ordered from high OORD to low OORD. If OORD (K) is greater than or equal to ORDMAX, the obstacle does not fall within the controlling interval. If OORD (K) is less than or equal to ORDMIN, not only does the obstacle lie outside the controlling interval, but so do remaining members of the list, and candidate obstacle selection can stop.

If the obstacle lies within both the primary and secondary intervals (checks on coordinate 0 in figure 47), interference computations are made for it (see 6.6). If the last obstacle in the list is within the primary interval, computations will stop because its successor LINKO is zero.

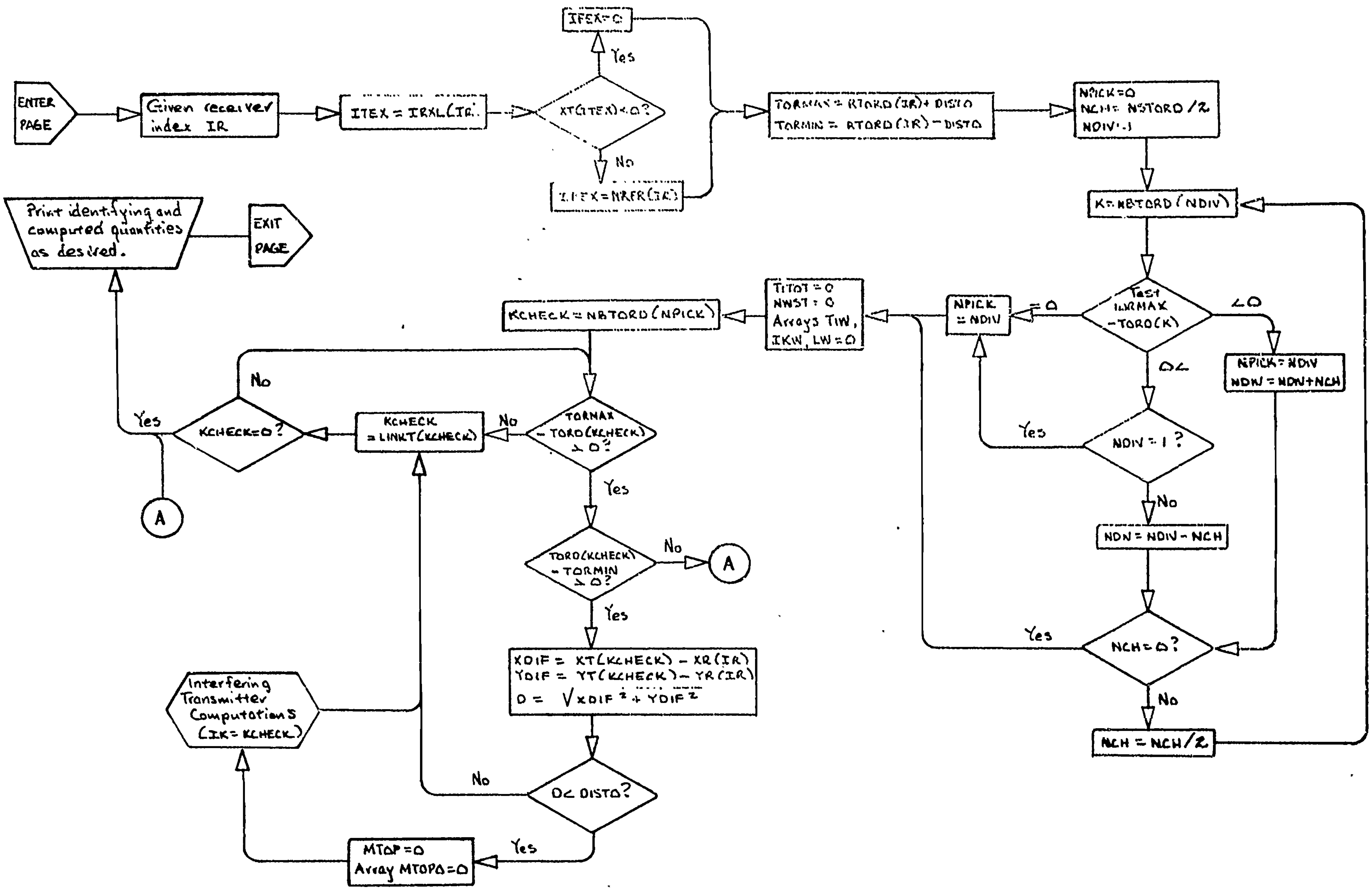
7.3 Candidate Interfering Transmitter Selection

The precomputation processing done in 5.2 is employed here. Selection of interfering transmitters is flowcharted in figure 49. Some variable definitions are in 4.3 and 5.2; others appear below.

Definitions:

- NCH - number of sections to advance or retreat in seeking starting section of list.
- NDIV - index of section currently being tested.
- NPICK - section of list at which search should begin.
- TORMAX - maximum ordered coordinate of interval within which interfering transmitters lie.
- TORMIN - minimum ordered coordinate of interval within which interfering transmitters lie.

Fig. 49 - CANDIDATE INTERFERING TRANSMITTER SELECTION



To begin the routine identifies the indices ITEX of the receiver's owning transmitter, and IFEX of its desired frequency at that transmitter. These values are required in the interfering transmitter computations (see 6.7).

From this point on the procedure is very similar to that described in 7.2. The interval TORMIN-TORMAX that will control the list search is defined using the receiver coordinate RTORD that corresponds to the ordering coordinate TORD for the transmitter list. Then the section NPICK in the ordered transmitter list where searching should start is determined by a duplicate of the scheme in figure 47.

Since all interference signals calculated during the member-by-member search will contribute to the total interference TITOT and may affect the "worst interference source" arrays TIW, IKW and LW (6.7), the latter are initialized before the search starts. Beginning with list member NBTORD (NPICK), the coordinate TORD of each list member KCHECK is compared with TORMAX. When TORD falls between TORMAX and TORMIN and KCHECK also lies within the circle having radius DISTO and center at receiver IR, interference calculations are made on KCHECK. Prior to the calculations at each transmitter the duplicate antenna height parameter MTOP and array MTOPO are initialized.

Interfering transmitter selection stops when TORD is less than or equal to TORMIN or when the successor LINKT to KCHECK is zero (end of the list).

Quantities that should be output folowing these calculations include PODBW (TITOT and if RIPWR is non zero) PRDB (RIPWR/ENPO+

TITOT) A flag of "high" or "low" can be printed if necessary after comparing the latter quantity with HSNDB or LSNDB, respectivley (see 3.0). The contents of arrays IKW, LW, and TIW should be printed, with TIW (L) = PODBW (TIW(L)] for each L.

7.4 Flow of the Complete Program

Figure 50 is the flow chart for the program itself. The processes described in 4.1 through 5.7 are performed in series to begin the program. Then the actual computations begin. Three variables that appear in figure 50 alone are defined here.

Definitions:

AVHGT -	average height of receiver antennas computed for transmitter I, feet.
THC -	total antenna footage computed for transmitter I.
VHC -	number of antennas for which height is computed, transmitter I.

When the program investigates receivers belonging to transmitter I, GTRAN loads general controls. If the transmitter has special controls NXSPC, the index is placed in NTCELL and the controls are loaded by STRAN. DTCHK then scans the four integer control parameters.

If the transmitter owns receivers (NRFST test) and there are special controls in the group (NGRSP test, see 5.4), processing begins at once. When no special controls are requested, a positive NCOMP initiates processing and a negative NCOMP bypasses the entire receiver group. If NCOMP is zero, the program can still make owner-receiver topography computations (NTOPO test) or an obstacle check (NOBST test).

Output transmitter identifying information might include transmitter label IXLBL and coordinates (with dummy flag if XT 0), along with any special controls in effect for the transmitter.

The program next inspects each receiver L belonging to transmitter I. If there are special controls NASPC on the receiver, STRAN load them. DTCHK then scans the control parameters.

If NCOMP is negative the receiver is bypassed. Otherwise all four integer control parameters are checked; if any are greater than zero, computations are to be made for the receiver. Note that if INTC (3) (=NPLOT) is positive and other parameters are zero, no computations will be made since plotting depends on the results of the topography routine.

Output receiver identifying information might include the receiver label IRLBL and coordinates, along with any special controls in effect for the receiver.

The path through computation routines for receiver L is largely self-explanatory. Results of calculations preceding each routine are necessary within it. Following owner-receiver topography computations (right edge of figure 50) the program sets IRHGT as the height HLOSR (see 6.4) if IRHGT was previously zero. This height is accumulated for use in figuring AVHGT when all receivers for transmitter I have been processed.

After computations for receiver L have concluded, the program returns to point C. When another receiver remains in the group (LINKR test), GTRAN reloads general controls, any special group controls are reloaded by STRAN (NTCELL test), and the program returns to the special control check for the next receiver L.

Fig. 50 - PROGRAM FLOW

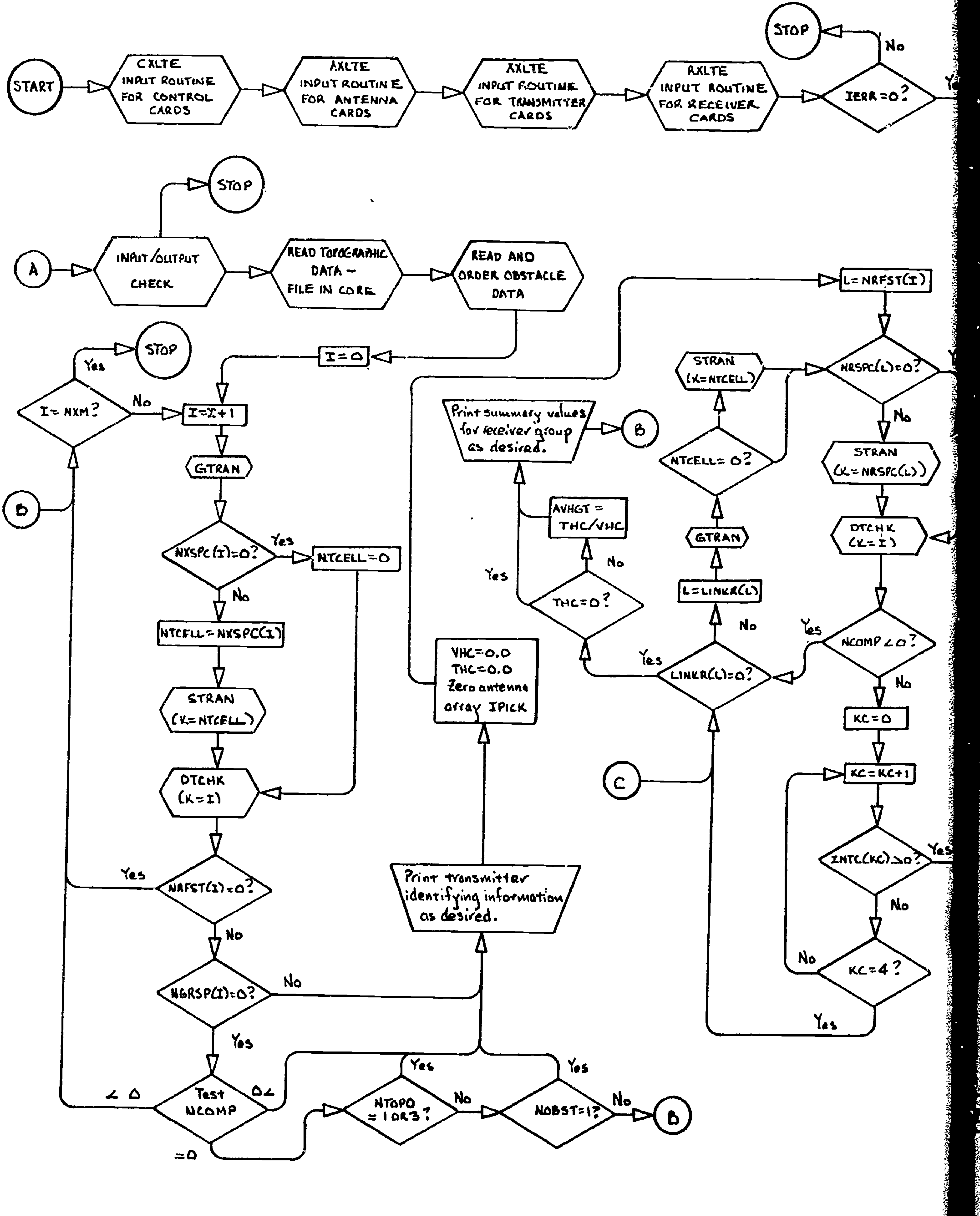
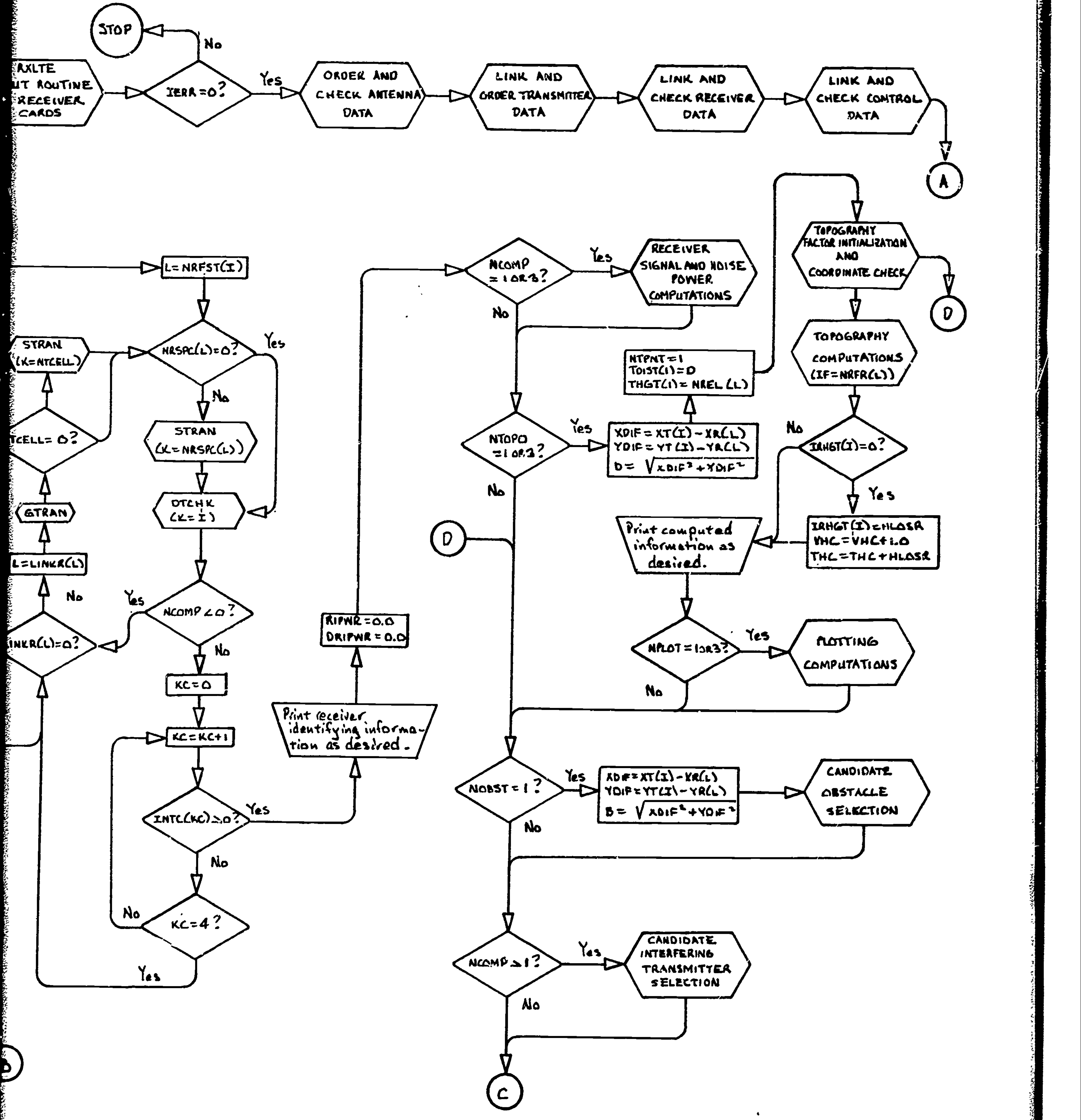


Fig. 50 - PROGRAM FLOW



If no receiver remains in transmitter I's group, output quantities for the group should include AVHGT (if nonzero) and the contents of antenna array IPICK (see 6.3). The program then returns to point B to process remaining groups of receivers.

Output values following the topography computations might include IK, L. IW, TDIST (IW),THGT (IW), HLOSR and HLOSO.

8.0 General Comments

For the most part variable names in the program follow the convention that integer variables begin with I,J,K,L,M, and N. Variables beginning with other letters are decimals. Two exceptions are LT and LR, defined in 6.3 and used again in 6.7.

Many of the expressions in the flowcharts involve mixed mode arithmetic (combinations of integer and decimal variables), particularly those using the integer signal frequency variables IRFR and ITXFR. Prior conversion of some variable values from one mode to another will be necessary to make expressions consistent if the program is implemented using a system that does not offer mixed mode arithmetic.

There is no obvious need for double-precision variables in the program, although initial operating experience may have some bearing on this. The variable TITOT could be defined as double-precision since for a single receiver it may accumulate many interference power values with a wide range of magnitudes.

Division by zero has been forestalled by 1) zero checks on input quantities and 2) epsilon comparisons on computed quantities (see 6.4, figure 37) used as divisors.

8.1 Storage Requirements

In the storage requirement expressions given below integer variables are assumed to occupy one-half machine word and decimal variables a full machine word.

Each transmitter location can broadcast up to 31 frequencies, the number of channels allotted for 2500 megacycle operation. The characteristics for each frequency occupy 2 1/2 words. Eight other words are required to describe the transmitter location and connect it properly within the program. The space required for transmitter data is:

85 1/2 words X maximum number of transmitters MNXM

Each antenna requires space for two pairs of tables, the azimuth-gain pairs for its primary and cross-polarizations. The variables LINKA and IALBL are also required for each antenna. Therefore antenna space takes up:

(1 word + 4 words x maximum number of points per table NPMAX) x maximum number of antennas MNANT.

The topography file or file segment in core occupies 1/2 x NXMCH x NYMCH words.

Each receiver needs variables occupying 10 words to describe it and link it properly in the program. The total space required for receiver data is:

10 words x maximum number of receivers MNRC

Variables describing and linking an obstacle take up 3 1/2 words. Thus total space required for the obstacle file is:

3 1/2 words x maximum number of obstacles NOBMX

As noted in 6.4 an upper limit should be placed on the terrain record arrays TDIST and THGT. The space needed for these arrays is:

2 x maximum number of points in terrain record

For program control (3.0) the required storage is:

27 1/2 + 8 x maximum number of SC cards NSCMX

The input control arrays (4.0) need approximately 200 words of space.

The array sizes needed for members heading sections of ordered lists, NBOORD (5.7) and NBTORD (5.2), can be computed using NOBMX and MNXM, respectively, with the formulas discussed in 5.0.2.

The above relations describe the size of the major blocks of data in the program. They can be used to estimate what space to allocate for each type of data.