APPENDIX G

COMPUTER INTERFERENCE/FREQUENCY ANALYSIS

This appendix contains a basic computer model which may be used in studying new frequency allocation plans and their effects on the existing electromagnetic structure.

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APPENDIX X-1. COMPUTER INTERFERENCE MODEL ANALYSIS

1.0 INTRODUCTION

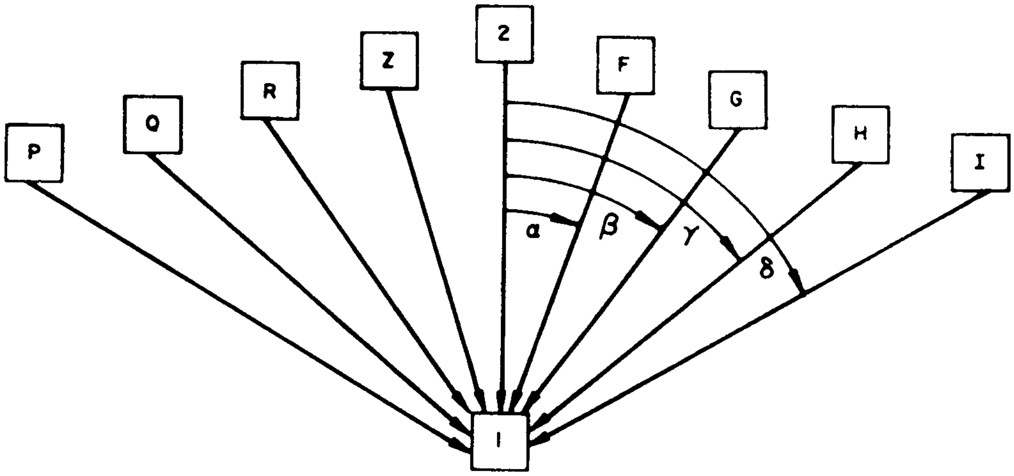
To perform his frequency engineering function the spectrum manager requires a model which analyzes the electromagnetic environment for him when the deployment of stations and the use of multiple frequencies and equipment types in changing terrains produce a complex situation. Such a model can be made useful for interference prediction, frequency selection, and engineering planning activities.

In interference prediction a model can contribute to understanding the nature of the sources and the susceptibility of the receivers, and therefore can assist in determining what course of action would best eliminate the interference. A model can also be made to select the best set of frequencies to ensure minimum potential interference. Similarly for engineering planning activities, a model can be used to study the effects of proposed new allocation plans, increased user density, increased traffic, etc., on the existing electromagnetic structure.

The model presented herein is a basic one and is not offered as the optimum model for satisfying all the needs of the spectrum manager. It is presented to show that mathematical/computer models can offer the spectrum manager a potentially powerful tool in his work and that, without some such model, the calculations and prediction methods become intractable.

2.0 CONFIGURATION MODEL

The computer model developed herein examines the interference environment for multiple variations of topography, frequency and equipment (transmitter, receiver and antenna) characteristics, and has been applied to several hypothetical microwave link configurations (Figure 1). The configuration of the model is geographically symmetrical and uses Site 1 as the common site for nine links. The topographical symmetry permits examination of the joint effects of several simultaneous variations: in this case azimuthal offset and



MICROWAVE NODE MODEL

FIGURE 1

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carrier frequency difference on relative interference levels. The primary link is designated Link 2-1, and is, for this analysis, geographically situated in a direct north-south direction (i.e., from 1 to 2) at an azimuth of 0° 00' 00". Each link has a path length of approximately 26.9 miles and the following azimuths (see Figure 1).

Link	Azimuth
F-1	0° 55' (α)
G-1	1° 50' (β)
H-1	2° 45' (γ)
I-1	4° 35' (δ)
Z-1	359° 05'
R-1	358° 10'
Q-1	357° 15'
P-1	355° 25'

Interference calculations are initially performed using a particular set of parameters. The interference calculations are then repeated with successive variation of these parameters. The resultant output from the computer program shows total interference levels at the receiver(s) at every site as a function of each parameter variation. Details of the computer program are discussed in paragraph 3.0.

The following parameters were chosen for the computer runs performed.

(a) The transmitter frequency at Site 2 always is equal to 6060 MHz.

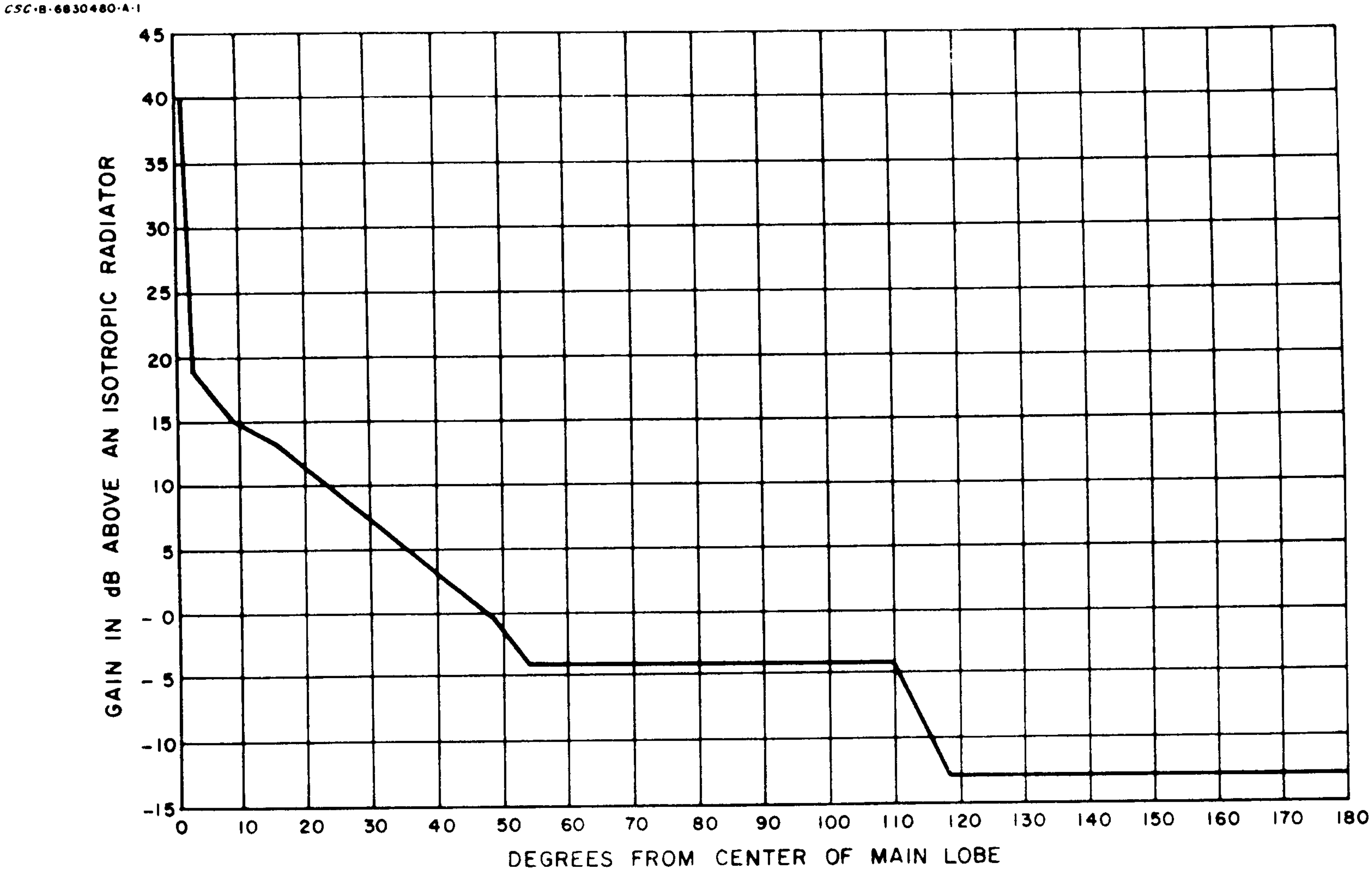
(b) The transmitter frequency at Sites F, G, H and I was chosen as 6060 MHz for run one and as 6040 MHz for run two.

(c) The transmitter frequency at Sites Z, R, Q and P was chosen as 6030 MHz for run one and 6050 MHz for run two.

(d) The frequency stability for both runs was chosen as ±1.8 MHz (i.e., approximately 3×10^{-2} percent).

(e) The transmitted power level for both runs was 5 watts (37.0 dBm) for all transmitters.

(f) The receiver and transmitter antenna patterns assumed for both runs were adapted from the Western Union 8-foot parabolic reflector at 6 GHz, vertically polarized, and are shown in Figure 2.



ANTENNA PATTERN
ADAPTED FROM WU 8 FT. PARABOLIC REFLECTOR AT 6 GHz, VERTICALLY POLARIZED

FIGURE 2

(g) The receiver selectivity curve employed for both runs was adapted from the General Electric TRS-696 receiver (960 VF channels), and is presented in Figure 3.

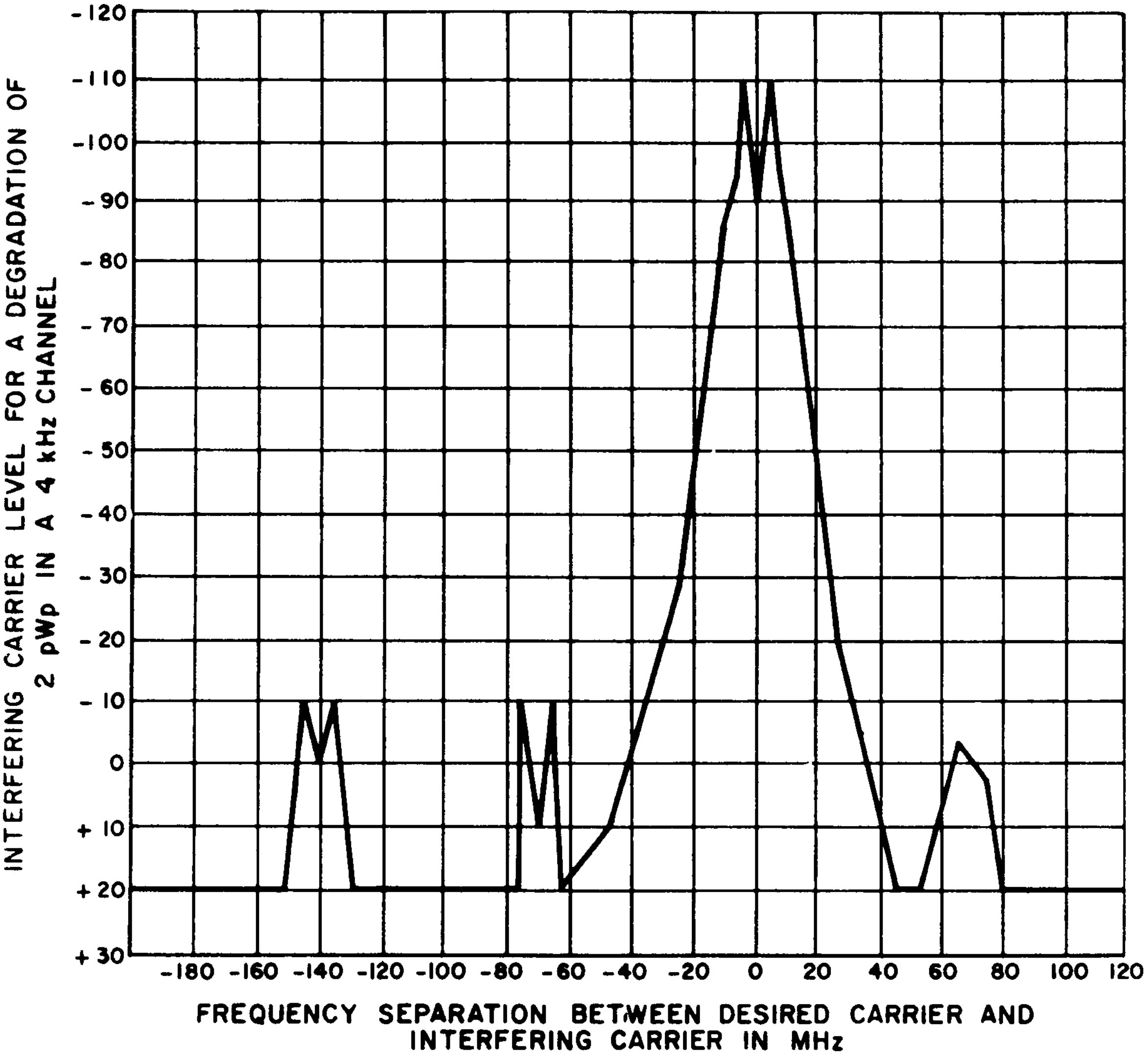
In the particular computer analyses performed, the most important results are the interference levels at the receiver of primary link 2-1 at Site 1, caused by all other secondary link (i.e., F-1, Z-1, G-1, H-1, etc.) transmissions to their respective receivers, which are located at Site 1. The interference levels at all other sites were also determined but, as expected, were well below those obtained at Site 1.

The pertinent computer print-out segments of runs one and two are presented in Figures 4 and 5 respectively. Figure 4 presents the interference level (i.e., relative interference) caused by secondary links transmitting at 6060 MHz (Δ f = 20 MHz) and 6050 MHz (Δ f = 10 MHz). For both runs the "desired signal strength" output is the wanted primary link signal (i.e., -23.6 dBm). All other dBm entries represent interfering signal strengths.

The results have been summarized and plotted in Figures 6 and 7. Figure 6 is a plot of the interference level at the Site 1 receiver of link 2-1 as a function of frequency separation between desired carrier and interfering carrier in MHz, with change in azimuth as a parameter. Figure 7 is a plot of the interference level at the Site 1 receiver of link 2-1 as a function of the change in azimuth between the primary link 2-1 and each of the interfering secondary links, with frequency separation as a parameter.

The zero dB interference level in both Figures 6 and 7 is referenced to a power level of 2 pWp at a zero transmission level point. A value of 2 pWp was arbitrarily used as a minimum tolerable interference level. Its selection does not bias the absolute levels of interference, but is used simply as a limit for the computer operation.

As an example of how the results of the computer runs may be employed in determining appropriate microwave link configurations for given interference level constraints, a 2-link system with a total



SELECTIVITY CURVE

ADAPTED FROM GENERAL ELECTRIC TRS-696 RECEIVER (960 VF CHANNELS)

FIGURE 3

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PRIMARY LINK STATION 1     - STATION 2    RECEIVING ON      6060.0 MC AT STATION 1

       SECONDARY LINK             TRANSMIT   INTERFERENCE
    A                 B           FREQ AT A   DBM  RELATIVE
STATION 2     - STATION 1           6060.0  -23.6    75.4
STATION F     - STATION 1           6060.0  -26.6    72.4
STATION G     - STATION 1           6060.0  -35.4    63.6
STATION H     - STATION 1           6060.0  -44.2    54.8
STATION I     - STATION 1           6060.0  -47.4    51.6
STATION P     - STATION 1           6030.0  -47.4   -25.5
STATION Q     - STATION 1           6030.0  -44.2   -22.3
STATION R     - STATION 1           6030.0  -35.4   -13.5
STATION Z     - STATION 1           6030.0  -26.6    -4.7

DESIRED SIGNAL STRENGTH = -23.6 DBM
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COMPUTER RUN 1

FIGURE 4

```
  PRIMARY LINK STATION 1    - STATION 2    RECEIVING ON     6060.0 MC AT STATION 1

          SECONDARY LINK             TRANSMIT   INTERFERENCE
          A                 B        FREQ AT A   DBM  RELATIVE
  STATION 2     - STATION 1          6060.0   -23.6    75.4
  STATION F     - STATION 1          6040.0   -26.6    27.7
  STATION G     - STATION 1          6040.0   -35.4    18.9
  STATION H     - STATION 1          6040.0   -44.2    10.1
  STATION I     - STATION 1          6040.0   -47.4     6.9
  STATION P     - STATION 1          6050.0   -47.4    44.0
  STATION Q     - STATION 1          6050.0   -44.2    47.2
  STATION R     - STATION 1          6050.0   -35.4    56.0
  STATION Z     - STATION 1          6050.0   -26.6    64.8

DESIRED SIGNAL STRENGTH = -23.6 DBM
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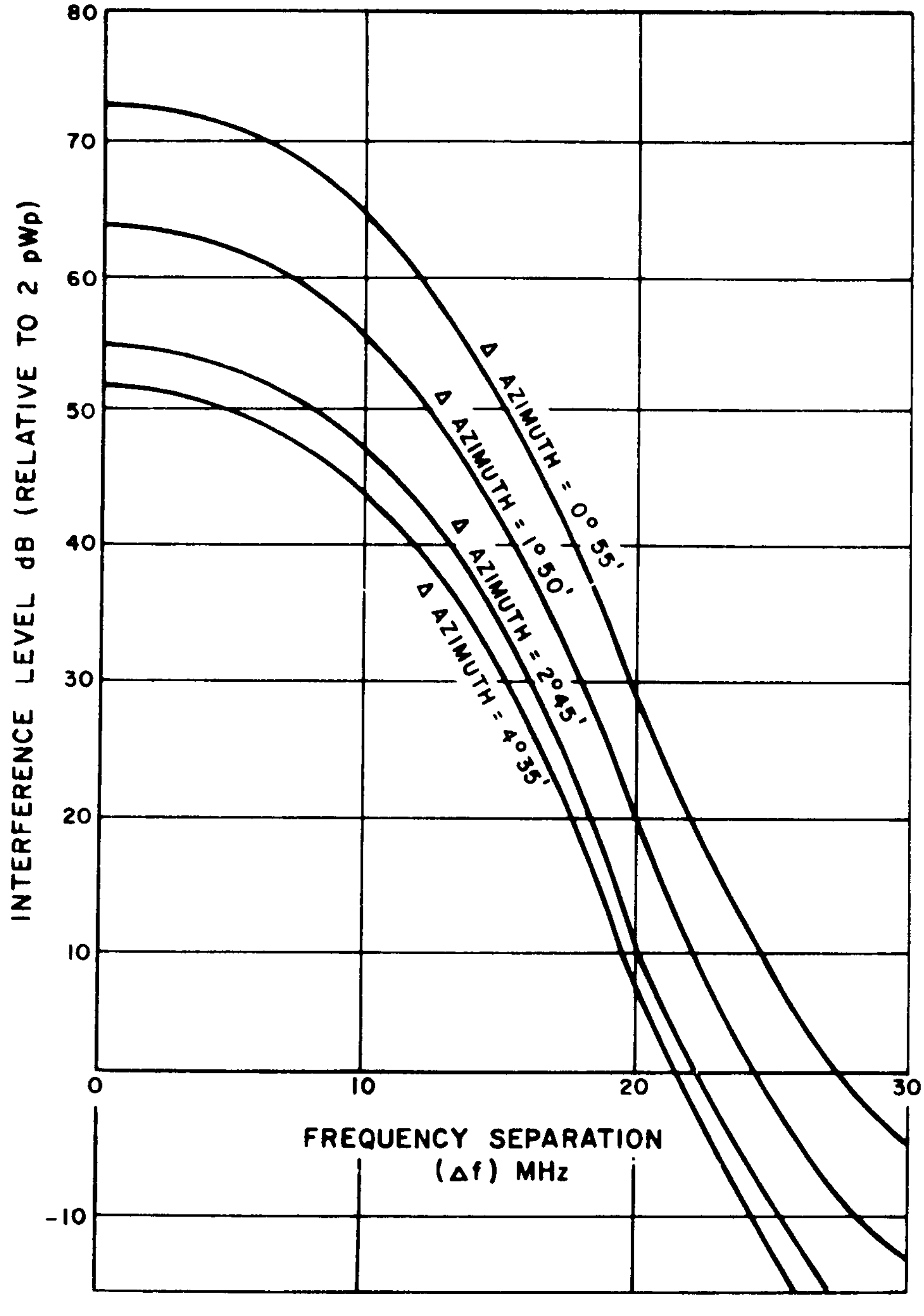
COMPUTER RUN 2

FIGURE 5



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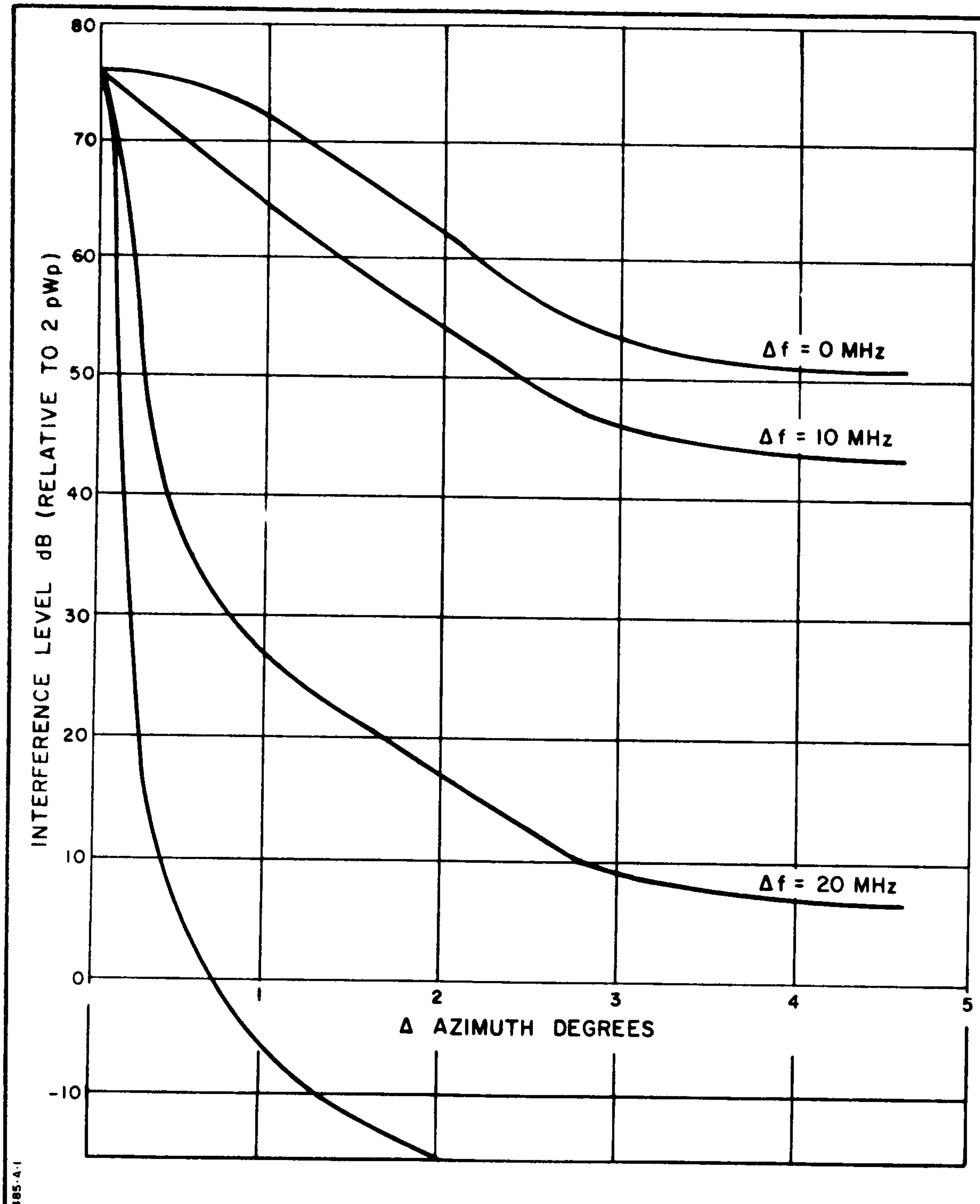
INTERFERENCE LEVEL VS FREQUENCY SEPARATION

FIGURE 6



INTERFERENCE LEVEL VS Δ AZIMUTH

FIGURE 7

interference level limit of 8 pWp (6 dB) is assumed. If the primary link operates with a transmitting frequency of 6060 MHz, then a second link transmitting at 6039.8 MHz must have an azimuth differential of at least 4° 35' to assure that the 8 pWp interference level is not exceeded. Alternatively, if a second site is located with a differential azimuth of only 2° 45', then it must transmit with a frequency difference of at least 21 MHz (6039 or 6081 MHz).

Multi-link configurations are examined by iteration of the same technique.

3.0 DESCRIPTION OF COMPUTER PROGRAM USED FOR INTERFERENCE MODEL

The program used for the calculations described in the preceding paragraph consists of two phases: a basic program and a modified program, both of which are described below. It is the modified program which has been used to perform the required calculation. The source language employed is FORTRAN IV for the IBM 7094.

3.1 FUNDAMENTAL PROGRAM

In a 9-link radio system, confined to a geographically limited area, there are at least 18 receivers, each of which may receive interference from as many as 17 transmitters. This situation can produce 306 potential interference cases. Most of these interference cases can be eliminated immediately by inspection, and a systematic approach to frequency selection can sometimes be used to assure that only a few potential significant interference cases occur. A severe problem arises when the network becomes extremely dense, and is colocated with existing installations that must be protected, such that systematic manual approaches no longer yield workable frequency plans. The feasibility of a plan depends on antenna patterns, reciever interference rejection characteristics and the network geometry. This computer program makes a routine calculation of the interference level at each receiver due to each transmitter, taking into account the antenna characteristics and relative path angles, the transmitter power, the free space propagation loss and the receiver characteristics. The cumulative signal level and the margin above or below the allowable level are printed.

Another printout from this program presents only those cases where the computed interference level is greater than a predetermined allowable level. Based on prior study of the network the planner may have a fairly good idea which transmitter-receiver combinations will appear on this list. Its main use is to point out cases he has overlooked and to indicate the expected magnitude of the interference.

The program assumes that free space line-of-sight propagation prevails between all stations of the network with intervening obstacles not protruding into the beam any deeper than the 0.6 Fresnel radius. This conservative assumption infers an infinite effective earth radius for some links: the engineer can through further investigation then decide to ignore computed interference cases he knows to be negligible because of terrain masking.

3.1.1 Limitations

In addition to the propagation calculation limitations, the following should be noted:

1. Inter-station interference due to carrier· frequency fundamentals only are considered. Cross-band (i.e., 2 GHz to 4 GHz interferences) are not properly computed because antenna patterns and the propagation loss equation do not apply. This is generally not a limiting factor since the amplitudes of harmonics are well below that of the fundamental frequency.
2. Polarization isolation is not considered. Any polarization discrimination, therefore, adds to the interference protection.
3. Harmonics, intermodulation, man-made or solar noise are not considered.
4. Terrain backscatter or antenna misalignment are not considered.

3.1.2 Overall Program Flow

The entire program consists of three routines (jobs) that are sequentially executed on the IBM 7094. The input for Job 1 consists of station indices and map coordinates in latitude and longitude. Its output is a listing of bearing and ranges from each station to every other station. Up to fifty stations (sites) may be simultaneously accepted. The listing is used mainly for cross checking and reference; the main output is a magnetic tape in binary format used as input to Job 2.

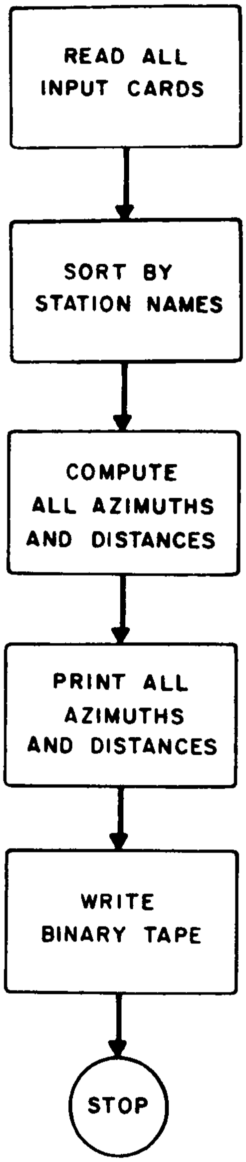
Job 2 accepts link defining cards that specify the topology of the network. From these and the output of Job 1, it computes relative angles for side lobe computation from each antenna to every other antenna. A frequency independent component of the path loss [20 LOG (distance)] is computed for later use in Job 3. A binary tape of distance, 20*ALOG10 (DIST), and the relative antenna angles are written as input to Job 3. A listing of this data is printed for reference.

One input for Job 3 is a card which defines the frequency band and the allowable limit of interference above receiver threshold. Another input is a set of cards which defines the characteristics of a set of receivers and antennas, specifying allowable interference level in dBm versus frequency and gain relative to isotropic for angles from the center of the main beam. Each receiver and antenna is given a unique number used in the next set of cards that specifies the frequency, transmitter power, receiver type and antenna types (at transmitter and receiver) used on each link of the system to be computed. Job 3 uses these cards, with the preprocessed geographic information from Job 2 to produce the final desired output.

In each job, the stations are identified by alphanumeric names which may contain as many as 12 characters. The programs search for the relevant data by these names, hence the spelling in Jobs 2 and 3, must be identical with the spelling in Job 1.

3.1.3 Flow Charts

Figues 8, 9, and 10 give simplified flow charts of the 3 jobs. Each block is a distinct segment with no branching to other blocks except as shown. The individual blocks may be fairly complicated internally, but the source program has liberal comments



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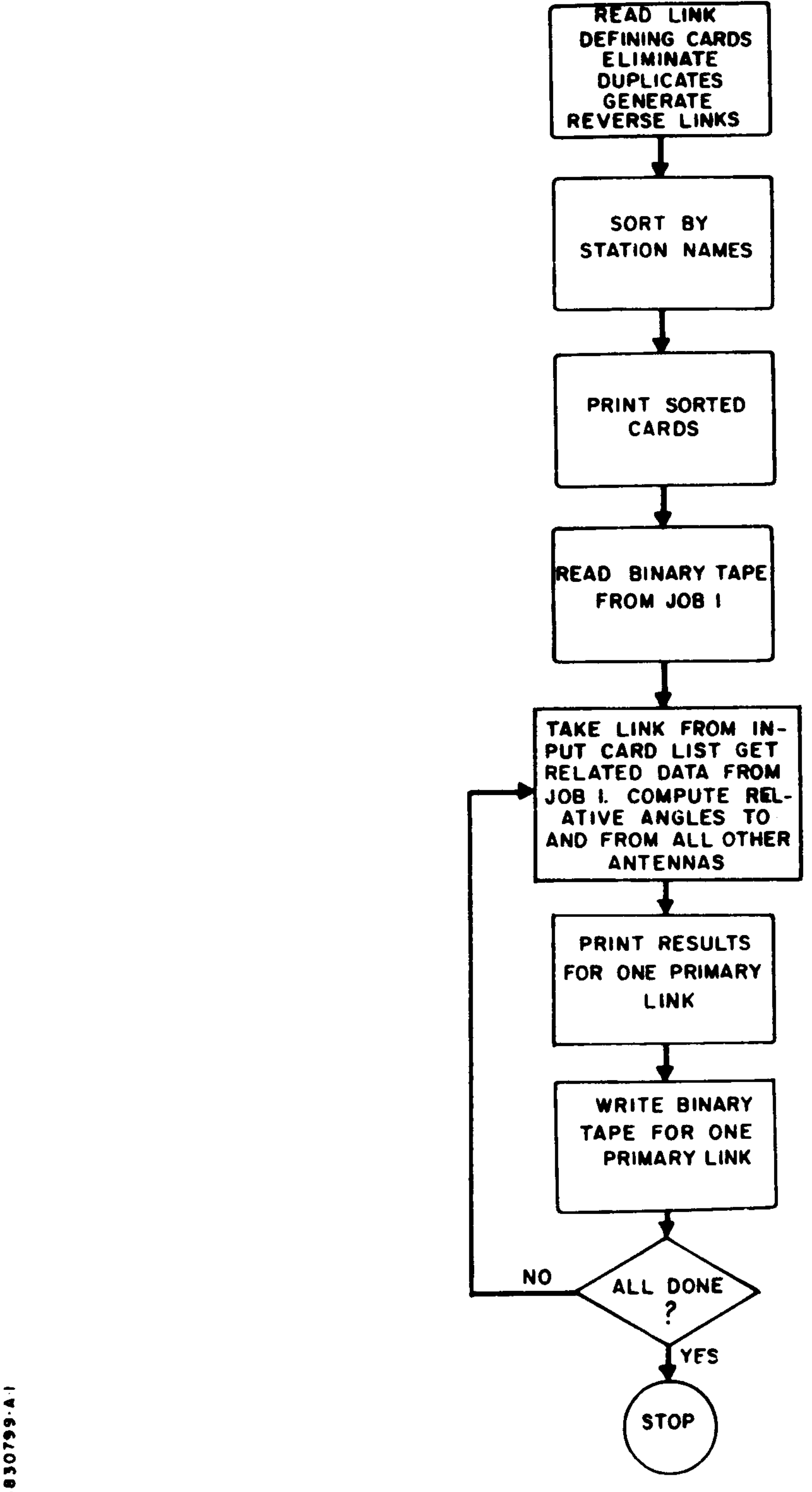
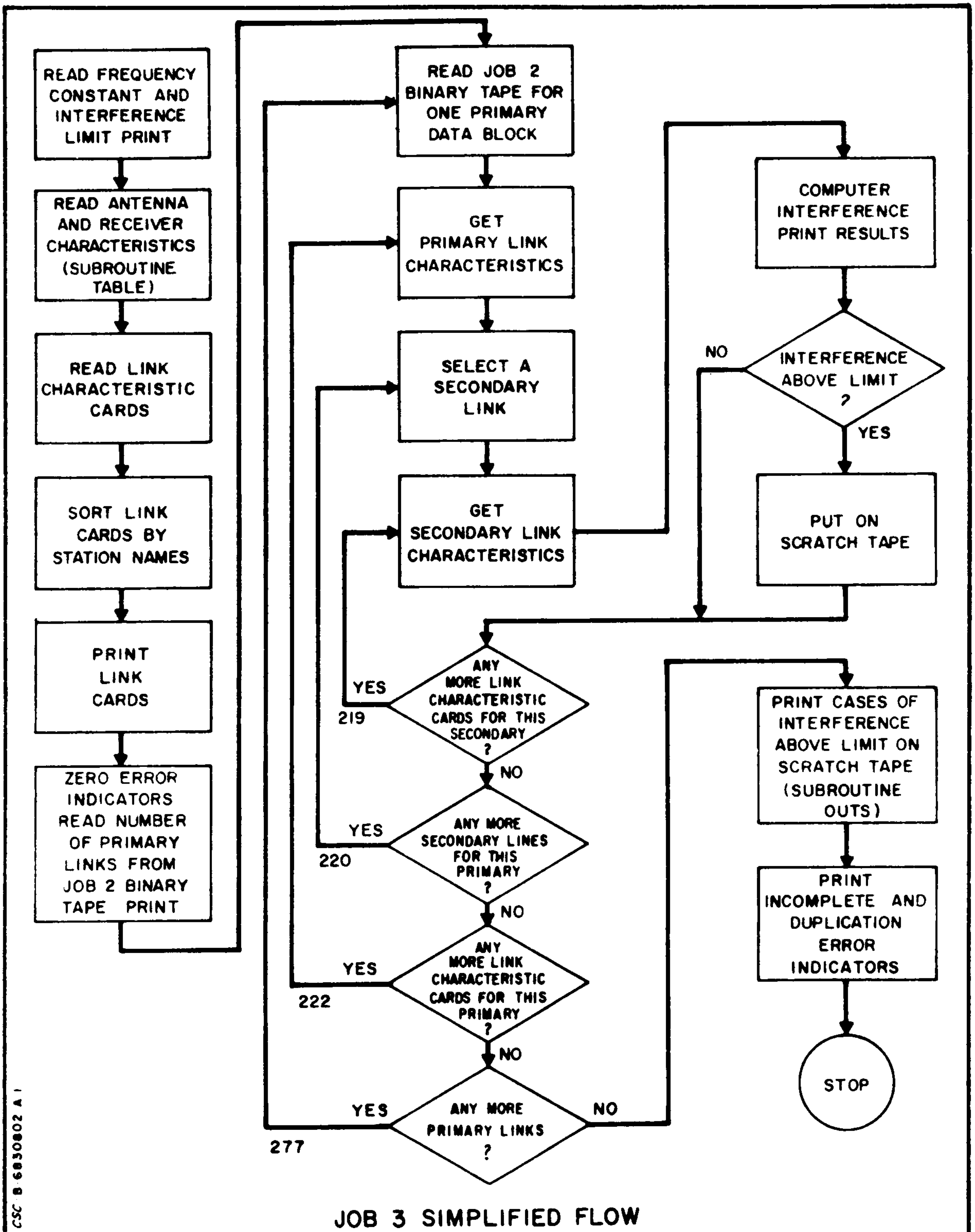
JOB I SIMPLIFIED FLOW

FIGURE 8



JOB 2 SIMPLIFIED FLOW

FIGURE 9



JOB 3 SIMPLIFIED FLOW

FIGURE 10

and, with the detailed statement-by-statement flow charts, can be easily followed. Two kinds of links are referred to:

A primary link is a transmitter at one station sending a desired signal to a receiver at another station; a secondary link is a transmitter-receiver pair sending an undesired (potentially interfering) signal to the receiver of the primary link. Note that links are unidirectional as far as the program is concerned. The usual two-way radio link is treated as two separate links.

3.2 MODIFIED PROGRAM

The modified program incorporates several changes to the fundamental program. These changes result in an output that is suitable for use by personnel not familiar with computer programming and processing. The basic part of this program is identical to the original program with two exceptions:

1. An additional scratch tape is used to record information on all interference links on the system.
2. Near the end of the program a subroutine is called which uses the information written on the scratch tape to evaluate the degree of interference at each station.

The program operates on the assumption that the receiver sensitivity characteristics are given as follows:

The receiver sensitivity characteristics is a plot of interference level vs. frequency spacing from the desired signal. Specifically, the curve should indicate the level of RF interference required to produce the maximum acceptable interference noise in any of the channels in the baseband of the receiver.

Each link is analyzed according to this specification and the results are printed based on the following criteria:

1. If the total interference noise on any link is less than the previously defined maximum baseband interference level, no interference information is listed.
2. If the total interference noise exceeds that level, then each link which contributes more than five percent of the total noise is listed, in order of descending noise contribution. All pertinent parameters, such as antenna type, distance, receiver type, azimuth, etc. are listed for the interference paths.

3. Additionally, the program provides a drift simulator. This part of the program makes slight changes in the values of the assigned transmitter and receiver frequencies to simulate the frequency stability characteristics. Presently, the program assumes and selects the worst case interference when the system drifts within the programmed limits. The value can be changed to simulate other stability characteristics.

3.2.1 Overall Program Flow

The basic program follows the same philosophy of the original program. The major change occurs when subroutine FORMA is called by the main program. At this point subroutine FORMA acts as an executive program to control the operation of sorting and printing the essential interference data on each primary link in the system. The basic operation of the executive program is as follows:

1. Initially, the program loads all pertinent data on a single primary link into a common one-dimensional array. This data has been previously written in binary format on scratch tape KUT 20.
2. Next the program proceeds to read another block of data representing a secondary interference link into another two-dimensional array (A). The program continues to read in blocks of data on secondary links until it senses that there are no more secondary links. This is done by testing each secondary link for a combination of variables which are unique to primary links. If a primary link is found, the tape is backspaced one logical record and the system stops reading links and proceeds to the next part of the program. During the time each logical record of the secondary links is being stored in the array A, a running total of the noise level in pWp is maintained.
3. At this point a check is made on the total noise of the system. If it is insignificant (i.e. below the assigned maximum level), the system abandons further processing of the primary link and proceeds to step 1 where it begins to process the next primary link. If a significant amount of noise is present, the system proceeds to step 4.
4. The program now calls subroutine SORT. This subroutine begins to scan array A to find the secondary link with the greatest amount of interference noise (pWp). This link is exchanged with

the first link in the array. The process is repeated for the next highest link and transfers made with the second link in the table, etc. Each time a change is made the noise is inspected to see if it is higher than the five percent level. If it is not, then the sorting process is stopped, since levels below this figure are insignificant and will not be printed in the final output.

5. After the sorting process stops, the SORT subroutine takes note of the number of significant secondary links which have been sorted and passes control back to the main program.

6. The main program then calls subroutine PRINT and transfers the sorted secondary array data and the primary link data to the PRINT subroutine. The final subroutine consists mainly of format statements, line counting and page numbering routines. Basically it takes the primary link data and prints it at the top of the page, then lists the significant secondary links in the order of importance, i.e., highest interference noise. Miscellaneous data on the total noise, difference, allowable limits, etc., are also computed and printed. After all significant interference links have been printed, control is passed back to executive subroutine FORMA where the system returns to the beginning of the subroutine. The next primary link and associated secondaries are read from tape KUT 20 and processed in the same manner.

The entire process is repeated until all primary and secondary links have been processed. When all links are printed, the executive program returns to the main program. The location in the main program is near the end, so for all practical purposes the program is finished and program execution is terminated by the main program.