INTERNATIONAL ATOMIC ENERGY AGENCY
UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION
INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS
I.C.T.P., P.O. BOX 586, 34100 TRIESTE, ITALY, CABLE: CENTRATOM TRIESTE

H4.SMR/841-18

FOURTH ICTP-URSI-ITU(BDT) COLLEGE ON RADIOPROPAGATION:
Propagation, Informatics and Radiocommunication System Planning

30 January - 3 March 1995

Miramare - Trieste, Italy

"Calculations on HF Propagation prediction"

Lecture 3

K.A. Hughes
International Telecommunications Union (ITU)
Geneva, Switzerland

Laboratory on Informatics for Radiocommunications

Calculations on HF Propagation prediction

For the questions below, you will make use of the computer program REC533A, which is a computerized version of the HF propagation prediction method contained in Recom. ITU-R PI.533. To access the program, go to the directory \DIR533A and type REC533A.

1. This month (February 1995), a beacon transmitter will operate from London (51.0°N, 0.0°W) on frequencies in the 6, 10, 14 and 26 MHz bands. The transmitter power is 10 kW and the antenna is isotropic. The Signal-to-Noise Ratio (SNR) required for 50 % of the time for reception in Trieste (46.0°N, 14.0°E) is 8 dB in a 6 kHz bandwidth. The man-made noise category is rural.

i) What frequencies are operable at 0500, 1200 and 2000 UT?

ii) For each hour of the day, which of the four frequencies is closest to the FOT?

iii) If the beacon continues to operate for several years, will the same frequencies as calculated for question (i) above still be available at:

- sunspot minimum (assume to be in February 1996 with a value of R12 = 5)
- sunspot maximum (assume to be in February 2001 with a value of R12 = 130)?

2. If the path described in question 1 above were reversed, i.e. transmitter in Trieste and receiver in the centre of London, which system parameter would require modification in the prediction?

Are the frequencies operable at 0500, 1200 and 2000 UT for February 1995, with a SNR of 8 dB, still the same as those calculated in question 1?

3. You are a radio amateur in New York (41.0°N, 73.0°W) with equipment operating with J3E modulation in the amateur HF bands at 7, 14, 18, 21 and 28 MHz. You wish to establish daily contact throughout the coming year (1995) with a colleague in Trieste (man-made noise category is rural) and you aim for a SNR of at least 5 dB. With a half-wave dipole antenna at your disposal for each band (types 120 to 124) and a transmitter power of 100 W, at what hours and in which frequency bands would you be able to establish contact?

4. Swedish Radio International (transmitter located in Stockholm, 59.5°N, 17.0°E) are reviewing their winter service into West Africa, and in particular are investigating reception in four locations, (all having a rural noise category):

Casablanca (33.0^{O}N, 7.5^{O}W)
Dakar (14.5^{O}N, 17.0^{O}W)
Ougadougou (12.5^{O}N, 1.5^{O}W)
Accra (6.0^{O}N, 0.0^{O}W)

Frequencies are available in the 7, 12 and 17 MHz bands. The transmitter power is 50 kW into a horizontal log-periodic antenna (type 500) with a bearing of 210^{O}. In order to achieve a minimum usable field strength of 26 dB(μV/m):

i) what is the minimum number of the available frequencies that could be used to provide service between 1000 and 2200 UT at all four locations and which are they? (Take January 1995 as a representative month);

ii) would the situation change if the transmitter power were increased to 500 kW?

5. Plans are underway for scientific data from Alice Springs, Australia, (24.0^{O}S, 133.0^{O}E) to be relayed to one of 3 possible Australian cities during winter (in southern hemisphere) 1998 when the sunspot number, R12, is estimated as 75. The candidate cities are:

Sydney (34.0^{O}S, 152.0^{O}E)
Adelaide (35.0^{O}S, 138.0^{O}E)
Perth (32.0^{O}S, 116.0^{O}E)

24 hour service is required with a SNR of 20 dB in a 300 Hz bandwidth. The transmitter feeds an isotropic antenna with a power of 100 W. Frequency assignments are available in bands at 5, 6, 8, 10, 12, 14, 18, 22 and 26 MHz.

i) Which is the best city for reception?

ii) In the frequency range 5 - 26 MHz, what are the two most suitable frequency bands in which to have assignments (i.e. those giving the highest reliabaility)?

6. An F1B teleprinter circuit at 50 baud with a character error ratio of 1 % and diversity reception is established this month (February 1995) over the path Lisbon (38.5^{O}N, 9.0^{O}W) to Geneva (46.5^{O}N, 6.0^{O}E) (rural noise category) using a monopole transmitting antenna (type 1009). The transmitter power is 5 kW. At what hours, and at what frequencies, will the probability (reliability) of achieving the desired SNR exceed 70 %? Frequencies available are at 6, 9, 12, 17 and 26 MHz. What will be the situation in 5 years time (with R12 estimated as 100)?

Date of circular: January 1995
Date de la circulaire: janvier 1995
Fecha de la circular: enero de 1995

YEAR ANNEE AÑO	MONTH MOIS MES	R_I	R_{12}^{*}	R_{12}^{**}	Φ	Φ_{12}	IG	IG_{12}	I_{F2}	$I_{F2_{12}}$
	1	59.1	71	71	117.2	124	69	79	50	71
	2	90.5	69	69	139.1	122	82	76	66	69
	3	70.5	67	67	135.0	119	93	73	78	66
	4	61.9	63	64	116.7	117	71	70	71	62
	5	61.2	60	60	114.9	113	58	66	56	58
1993	6	49.1	56	56	112.8	110	64	61	63	54
	7	57.3	55	55	102.2	109	59	58	53	51
	8	42.0	52	52	96.0	106	56	55	53	48
	9	21.7	49	48	88.0	102	38	51	26	45
	10	55.4	45	45	99.7	99	43	47	36	41
	11	34.8	41	41	93.8	96	33	44	31	37
	12	49.4	39	38	101.5	93	39	41	30	33
	1	58.8	37	37	111.3	92	50	38	38	30
	2	35.9	35	35	97.2	90	36	35	26	27
	3	31.7	34	34	89.5	90	37	34	40	25
	4	16.7	34	34	79.7	89	31	32	19	23
	5	18.2	33	33	81.7	87	22	31	7	22
1994	6	28.1	31	31	79.7	86	25		13	
	7	35.0	***30***	***29***	83.2	***83***	29		24	
	8	22.8	***28***	***27***	78.0	***80***	24		14	
	9	26.7	***27***	***25***	79.9	***77***	30		12	
	10	43.8	***25***	***24***	87.1	***78***	19		10	
	11	18.0	***24***	***23***	79.1	***80***	19		12	
	12	26.7	***23***	***22***	81.5	***80***				
	1		***22***	***22***		***80***	**Predictions for IG_{12} and $I_{F2_{12}}$ unavailable**			
	2		***21***	***21***		***77***				
	3		***20***	***20***		***76***				
	4		***19***	***19***		***74***				
	5		***18***	***18***		***73***				
1995	6		***17±5***	***18***		***74***				
	7		***16***	***17***		***74***				
	8		***15***	***17***		***76***				
	9		***14***	***16***		***77***				
	10		***13***	***16***		***77***				
	11		***12***	***15***		***77***				
	12		***11±5***	***14***		***76***				

For legend to Table, see next page.
Pour la légende du Tableau, voir la page suivante.
Para la leyenda del cuadro, véase la pagina siguiente.

BANDWIDTHS, SIGNAL-TO-NOISE RATIOS AND FADING ALLOWANCES IN COMPLETE SYSTEMS

(Question 1/3, Study Programme 1A/3)

(1951-1953-1956-1963-1966-1970-1974-1978-1982-1986)

The CCIR,

CONSIDERING

(a) that the studies requested in Study Programme 1A/3 have not yet been completed, and that it is desirable to classify the important points with which future studies will have to deal;

(b) that there is a need for numerical values which take into account fading and fluctuations in field intensity;

(c) that, however, the information contained in Annex I to Recommendation 313 and Report 266 gives some results from which provisional data on fading allowances can be derived,

UNANIMOUSLY RECOMMENDS

1. that meanwhile, the values given in Table I should be adopted as provisional values for the signal-to-noise ratio required for the class of emission concerned;

2. that meanwhile, the values given in the last two columns of Table I, in conjunction with the estimate of the intensity fluctuation factor given in Note 4 to this Table, may be used as an aid to estimate monthly-median values of hourly-median field intensities necessary for the various types and grades of service;

3. that Table I be extended to include additional systems as the pertinent information becomes available;

4. that the studies in connection with Study Programme 1A/3 should be continued, in conjunction with those of Study Programme 28A/6, for the purpose of determining whether the provisional values given in the Table may be accepted or should be modified.

Note 1. – In these studies, the procedures given in Report 195 should be given full consideration. Reports 413, 414 and 415 (Oslo, 1966) may also be consulted.

Note 2. – Use of the provisional recommended values only permits an estimate to be obtained, which may have to be adjusted for radio circuits of different lengths depending on the grade of service required.

TABLE 1 – *Required signal-to-noise ratios*

Class of emission	Pre-detection bandwidth of receiver (Hz)	Post-detection bandwidth of receiver (Hz)	Grade of service	Audio signal-to-noise ratio (1) (dB)	RF signal-to-noise density ratio(2) (3) (dB): Stable condition	RF signal-to-noise density ratio(2) (3) (dB): Fading condition (4) non-diversity	RF signal-to-noise density ratio(2) (3) (dB): Fading condition (5) dual diversity
A1A Telegraphy 8 bauds	3000	1500	Aural reception (6)	– 4	31	38	
A1B Telegraphy 50 bauds, printer	250	250	Commercial grade (7)	16	40		58
A1B Telegraphy 120 bauds, undulator	600	600		10	38		49
A2A Telegraphy 8 bauds	3000	1500	Aural reception (6) (19)	– 4	35	38	
A2B Telegraphy 24 bauds	3000	1500	Commercial grade (7) (19)	11	50	56	
F1B Telegraphy 50 bauds, printer $2D$ = 200 Hz to 400 Hz	1500	100	$P_c = 0.01$ $P_c = 0.001$ $P_c = 0.0001$ } (8)		45 51 56 } (9)	53 63 74 } (9)	45 52 59 } (9)
F1B Telegraphy 100 bauds, printer $2D$ = 170 Hz, ARQ	300	300	(10)		43	52	
F7B Telegraphy 200 bauds, printer $2D$ = ..., ARQ			(10)				
F1B Telegraphy MFSK 33-tone ITA2 10 characters/s	400	400	$P_c = 0.01$ $P_c = 0.001$ $P_c = 0.0001$ } (8)		23 24 26	37 45 52 } (25)	29 34 39
F1B Telegraphy MFSK 12-tone ITA5 10 characters/s	300	300	$P_c = 0.01$ $P_c = 0.001$ $P_c = 0.0001$ } (8)		26 27 29	42 49 56 } (25)	32 36 42
F1B Telegraphy MFSK 6-tone ITA2 10 characters/s	180	180	$P_c = 0.01$ $P_c = 0.001$ $P_c = 0.0001$ } (8)		25 26 28	41 48 55 } (25)	31 35 41
F7B Telegraphy							
R3C Phototelegraphy 60 rpm	3000	3000			50	59	
F3C Phototelegraphy 60 rpm	1100	3000	Marginally commercial (22) Good commercial (22)	15 20	50 55	58 65	
A3E Telephony double sideband	6000	3000	Just usable (11) Marginally commercial (12) Good commercial (13)	6 15 33 } (18)	50 59 67(14)	51 64 75(14) } (20)	48 60 70(14) } (15) (20)
H3E Telephony single-sideband full carrier	3000	3000	Just usable (11) Marginally commercial (12) Good commercial (13)	6 15 33 } (18)	53 62 70(14) } (23)	54 67 78(14) } (20)	51 63 73(14) } (15) (20)
R3E Telephony single-sideband reduced carrier	3000	3000	Just usable (11) Marginally commercial (12) Good commercial (13)	6 15 33 } (18)	48 57 65(14) } (24)	49 62 73(14) } (20)	46 58 68(14) } (15) (20)
J3E Telephony single-sideband suppressed carrier	3000	3000	Just usable (11) Marginally commercial (12) Good commercial (13)	6 15 33 } (18)	47 56 64(14)	48 61 72(14) } (20)	45 57 67(14) } (15) (20)
B8E Telephony independent-sideband 2 channels	6000	3000 per channel	Just usable (11) Marginally commercial (12) Good commercial (13)	6 15 33 } (18)	49 58 66(14)	50 63 74(14) } (20)	47 59 69(14) } (15) (20)
B8E Telephony independent-sideband 4 channels	12000	3000 per channel	Just usable (11) Marginally commercial (12) Good commercial (13)	6 15 33 } (18)	50 59 67(14)	51 64 75(14) } (20)	48 60 70(14) } (15) (20)
J7B Multichannel V.F. telegraphy 16 channels 75 bauds each	3000	110 per channel	$P_c = 0.01$ $P_c = 0.001$ $P_c = 0.0001$ } (8)		59 65 69 } (21)	67 77 87 } (21)	59 66 72 } (21)
J7B Multichannel V.F. telegraphy 15 channels 100 bauds each with ARQ	3000	110 per channel	(10)				
R7B Multichannel V.F. telegraphy reduced carrier							
B7W Composite 16 channels 75 bauds each 1 telephony channel(16)	6000	110 per telegraphy channel 3000 for the telephony channel	$P_c = 0.01$ $P_c = 0.001$ $P_c = 0.0001$ } (8)		60 66 70 } (17)	68 78 88 } (17)	60 67 73 } (17)

Footnotes to Table I

(1) Noise bandwidth equal to post-detection bandwidth of receiver. For an independent-sideband telephony noise bandwidth equal to the postdetection bandwidth of one channel.

(2) The figures in this column represent the ratio of signal peak envelope power to the average noise power in a 1 Hz bandwidth except for double-sideband A3E emission where the figures represent the ratio of the carrier power to the average noise power in a 1 Hz bandwidth.

(3) The values of the radio-frequency signal-to-noise density ratio for telephony listed in this column, apply when conventional terminals are used. They can be reduced considerably (by amounts as yet undetermined) when terminals of the type using linked compressor-expanders (Lincompex) are used (see Report 354). A speech-to-noise (r.m.s. voltage) ratio of 7 dB measured at audio-frequency in a 3 kHz band has been found to correspond to just marginally commercial quality at the output of the system, taking into account the compandor improvement.

(4) The values in these columns represent the median values of the fading signal power necessary to yield an equivalent grade of service, and do not include the intensity fluctuation factor (allowance for day-to-day fluctuation) which may be obtained from Report 252-2 + Supplement (published separately) in conjunction with Report 322 (published separately). In the absence of information from these Reports, a value of 14 dB may be added as the intensity fluctuation factor to the values in these columns to arrive at provisional values for the total required signal-to-noise density ratios which may be used as a guide to estimate required monthly-median values of hourly-median field strength. This value of 14 dB has been obtained as follows:

The intensity fluctuation factor for the signal, against steady noise, is 10 dB, estimated to give protection for 90% of the days. The fluctuations in intensity of atmospheric noise are also taken to be 10 dB for 90% of the days (see Study Programme 1A/3). Assuming that there is no correlation between the fluctuations in intensity of the noise and those of the signal, a good estimate of the combined signal and noise intensity fluctuation factor is

$$\sqrt{10^2 + 10^2} = 14 \text{ dB}.$$

(5) In calculating the radio-frequency signal-to-noise density ratios for rapid short-period fading, a log-normal amplitude distribution of the received fading signal has been used (using 7 dB for the ratio of median level to level exceeded for 10% or 90% of the time) except for high-speed automatic telegraphy services, where the protection has been calculated on the assumption of a Rayleigh distribution. The following notes refer to protection against rapid or short-period fading.

(6) For protection 90% of the time.

(7) For A1B telegraphy, 50 baud printer: for protection 99.99% of the time. For A2B telegraphy, 24 bauds: for protection 98% of the time.

(8) The symbol P_c stands for the probability of character error.

(9) Atmospheric noise ($\overline{V_d}$ = 6 dB) is assumed (see Report 322).

(10) Based on 90% traffic efficiency.

(11) For 90% sentence intelligibility.

(12) When connected to the public service network: based on 80% protection.

(13) When connected to the public service network: based on 90% protection.

(14) Assuming 10 dB improvement due to the use of noise reducers.

(15) Diversity improvement based on a wide-spaced (several kilometres) diversity.

(16) Transmitter loading of 80% of the rated peak envelope power of the transmitter by the multi-channel telegraph signal is assumed.

(17) Required signal-to-noise density ratio based on performance of telegraphy channels.

(18) For telephony, the figures in this column represent the ratio of the audio-frequency signal, as measured on a standard VU-meter, to the r.m.s. noise, for a bandwidth of 3 kHz. (The corresponding peak signal power, i.e. when the transmitter is 100% tone-modulated, is assumed to be 6 dB higher.)

(19) Total sideband power, combined with keyed carrier, is assumed to give partial (two element) diversity effect. An allowance of 4 dB is made for 90% protection (8 bauds), and 6 dB for 98% protection (24 bauds).

(20) Used if Lincompex terminals will reduce these figures by an amount yet to be determined.

(21) For fewer channels these figures will be different. The relationship between the number of channels and the required signal-to-noise ratio has yet to be determined.

(22) Quality judged in accordance with article 23.1 of ITU publication "Use of the standardized test chart for facsimile transmissions".

(23) For class of emission H3E the levels of sideband signals and pilot-carrier corresponding to 100% modulation are each −6 dB relative peak envelope power (p.e.p.). SSB receiver used for reception.

(24) For class of emission R3E the pilot-carrier level of −20 dB relative to p.e.p. is applied and the level of the sideband signal corresponding to 100% modulation is 1 dB lower than the p.e.p.

(25) Dependent on fading rate, typical values shown.

SECTION 6C: IONOSPHERIC PROPAGATION AND OPERATIONAL FORECASTING

RECOMMENDATION 373-6 *

DEFINITIONS OF MAXIMUM AND MINIMUM TRANSMISSION FREQUENCIES

(Question 25/6)

(1959-1963-1966-1970-1974-1978-1982-1990)

The CCIR,

CONSIDERING

that prediction services, scientists and operators have different requirements for definitions of the maximum and minimum transmission frequency,

UNANIMOUSLY RECOMMENDS that the following definitions should be used:

1. *operational MUF*, or simply *MUF*, is the highest frequency that would permit acceptable performance of a radio circuit by signal propagation via the ionosphere between given terminals at a given time under specified working conditions;

lowest usable frequency (LUF) is the lowest frequency that would permit acceptable performance of a radio circuit by signal propagation via the ionosphere between given terminals at a given time under specified working conditions.

Note 1 – Acceptable performance may for example be quoted in terms of maximum error ratio or required signal/noise ratio.

Note 2 – Specified working conditions may include such factors as antenna types, transmitter power, class of emission and required information rate;

2. *basic MUF* is the highest frequency by which a radio wave can propagate between given terminals, on a specified occasion, by ionospheric refraction alone.

ANNEX I

1. The *Optimum Working Frequency* (OWF or FOT) is the lower decile of the daily values of operational MUF at a given time over a specified period, usually a month. That is, it is the frequency that is exceeded by the operational MUF during 90% of the specified period.

2. Where the basic MUF is restricted to a particular ionospheric propagation mode, the values may be quoted together with an indication of that mode (for example, 1E MUF, 2F2 MUF).

If the extraordinary component of the wave is involved, then this is noted (for example, 1F2 MUF(X)). Absence of a specific response to the magnetoionic component implies that the quoted value relates to the ordinary wave.

It is sometimes useful to quote the ground range for which the basic MUF applies. This is indicated in kilometres following the indication of the mode type (for example, 1F2 (4000) MUF(X)).

---

* The Director, CCIR, is requested to bring this Recommendation to the attention of International Radio Science Union (URSI) and Study Groups 3, 7, 8 and 10 and the CCV.

MICROCOMPUTER IMPLEMENTATION OF THE
PROPAGATION MODEL OF RECOMMENDATION ITU-R PI.533
(WITH RECOMMENDATION ITU-R BS.705 ANTENNA GAIN PACKAGE)

PROGRAM HANDBOOK

by

M I Dick, S M Harrison

Rutherford Appleton Laboratory, UK

and

H Sizun

CNET, France Telecom, Lannion, France

ITU RADIOCOMMUNICATION BUREAU
July 1993

Table of contents

Page No.

List of figure captions **Page No**

List of table captions **Page No**

1. Introduction

This handbook describes program REC533A version 2.0 21 July 1993, a microcomputer implementation of the method of Recommendation 533. This program incorporates improved modelling of antenna gain using a package developed by DG2 and DG9 of Radiocommunication Working Party WP-6A from code originally written in the ex-CCIR Secretariat to meet the needs of HF broadcast planning. Values of directivity gain are evaluated for a series of frequencies by program DGCALC and are subsequently accessed by program REC533A. These programs and handbook replace an earlier implementation, program REC533, and the accompanying documentation

In this handbook sections 2-3 inform the user how to implement and run the programs. Section 4 presents the output options. Sections 5-6 provide additional information relating to the associated data base of reference ionospheric numerical data, and to the program languages and their compilation.

2. Configuration

2.1 Hardware requirements

Using the disks supplied the program requires a system with at least a single HD(high density) disk drive running under MS-DOS 2.1 (or later version) with an INTEL 8086 or later processor, 640 kbytes of memory and CGA,EGA or VGA graphics card.

2.2 Implementation

2.2.1 Disk content

The program is supplied on three HD floppy disks with contents as follows:

2.2.1.1 Disk 1 (binary object code)

In directory DIR533A:

(i) File INP533A.EXE - cursor-interactive input generator.

(ii) File REC533A.EXE - program REC533A for systems with a math's co-processor.

(iii) Files HGCGRAPH.COM, CGAGRAPH.COM and EGAGRAPH.COM - built-in graphics packages for HGC, CGA and EGA graphics cards respectively (section 2.2.3); also associated font size files 14X9.FON, 4X6.FON, 8X8.FON and error message file ERROR.MSG.

(iv) File CGRAPH.EXE - stand-alone graphics package, runs as a separate program accessing the graphics output file CGRAPH.OUT generated by program REC533A

(v) Files REP89401.BIN, REP89402.BIN... - binary reference ionospheric numerical data (CCIR Data Disk Set A)for the months JAN, FEB etc.

(vi) File DEFINEF.DAT containing subsets of the information in directory CIRDATA

(vii) File ANTENNA.INI - run-time initialisation file

(ix) File DGCALC.EXE - cursor-interactive antenna model parameter generator and component file DGFREQ.EXE for systems with a math's co-processor.

(xi) File MULTICOP.EXE, required to print with correct page throws and spacings output previously directed to a disk file.

(xii) File BIN2TXT.EXE- used internally by program REC533A for reading TURBO PASCAL 6 byte binary records antenna files.

(xiii) Example ASCII files 'nnnnANT.29F' -antenna modelling parameters at frequencies 2,3...30 MHz

(xiv) File READ.ME - information and advice for the user

Two further directories:

(vi) Directory CIRDATA holding circuit input data sets .

(viii) Directory ANTENNAE holding antennae input data sets.

2.2.1.2 Disk 2 (source code and data)

In directory DIR533A:

(i) Cursor-interactive input generator file INP533A.PAS and component file SMHANT.PAS (Turbo Pascal 6).

(ii) File REC533A.FOR program REC533A (FORTRAN 77).

(iii) File CGRAPH.BAS . (Quick Basic 4).

(iv) Files REP89401.DAT,REP89402.DAT......REP89405.DAT - formatted reference ionospheric data for the months January-May.

(v) File CONV2A.FOR - program to convert the reference data above (and that of section 2.2.1.3 below) to the binary CCIR Data Disk Set A of section 2.2.1.1(vi). (FORTRAN 77)

(vi) Cursor-interactive antenna modelling program DGCALC.PAS(Turbo Pascal 6) and component files DGANT.PAS(Turbo Pascal 6), DGFREQ.FOR (Fortran 77)

(vii) BIN2TXT.PAS - source code of BIN2TXT.EXE

2.2.1.3 Disk 3(source data cont.)

In directory DIR533A:

(i) Files REP89406.DAT,REP89407.DAT......REP89412.DAT - formatted reference ionospheric data for the months June-December

(ii) File REC533AX.EXE - as above in 2.2.1.1(ii), but for systems without a co-processor.

(iii) File DGCALCX.EXE and component file DGFREQX.EXE - as above in 2.2.1.1(ix), but for systems without a co-processor.

2.2.2 Directory CIRDATA and file DEFINEF.DAT

Using the files supplied, directory CIRDATA holds a library of data files each of which relates to a single path/time/operating conditions combination referred to as a circuit data set. Selected items from these circuit data sets are contained within file DEFINEF.DAT which is held in the same directory as the program files (REC533A.EXE etc.). Both the content of directory CIRDATA and file DEFINEF.DAT are updated automatically by the input generator. The user **should not modify** either independently of the other.

Further, using the files supplied, directory CIRDATA must be attached directly to the root directory as follows:

C:\CIRDATA where C is the disk drive

Where the program files(including DEFINEF.DAT, etc.) are copied to this drive it is suggested that they be placed in a directory at the same level i.e. C:\DIR533A. These files must be on the same drive as directory CIRDATA if the content of the run-time initialisation file ANTENNA.INI in not altered. For further information see section 2.2.6 below.

2.2.3 Directory ANTENNAE

Directory ANTENNAE holds a library of binary data files ('antenna data sets') 'ANTnnnn.DAT', where nnnn is a 3 or 4 digit antenna reference number(section 3.1.4.4). Each contains the parameters(type, number of elements, etc.) specifying a single antenna. The content of directory ANTENNAE is updated automatically by the input generator.

Using the files supplied, this directory must be attached directly to the root directory as follows:

C:\ANTENNAE where C is the disk drive

The data file for antenna number 'nnnn', and the corresponding ASCII modelling 'nnnnANT.29F' (section 3.1.4.1) and run-time 'nnnnANT.DAT' files of directory '\DIR533A' may be deleted if that antenna is not used by a circuit data set. If accidentally deleted the first two of these files will need to be re-generated using program DGCALC(section 2.2.9).

2.2.4 Simple set-up of program REC533A on a hard disk drive

Create directories DIR533A, CIRDATA, and ANTENNAE on a hard disk drive on drive C and copy the contents from the corresponding directories of disk 1. Using the DOS command XCOPY and the parameter 'S' permits the directory creation and copying processes to be undertaken in one operation by the system as follows, where the supplied disks are placed in turn in floppy disk drive A-

XCOPY A: C:/S

If no math's co-processor is fitted program REC533AX.EXE, DGCALCX.EXE and DGFREQX.EXE should be copied from directory DIR533A on DISK 3 to directory C:DIR533A

2.2.5 Alternative set-up of progran REC533A on a hard disk drive

However, the user can ,if desired , use different names for his/her directories and change directory levels or disk drives by modifying the run-time initialisation file of section 2.2.6 below. This file must in the directory holding REC533A and its associates files. If no math's co-processor is fitted the appropriate alternative programs can be found on disk 3(see 2.2.4 above)

2.2.6 Run-time initialisation file ANTENNA.INI

As supplied, this file contains the following data:

\ANTENNAE\ANT????.DAT
PARAMS.DAT
\CIRDATA\
DEFINEF.DAT

It is read when program INP533A is loaded and enables the directories, ANTENNAE and CIRDATA, containing the antenna and circuit data sets respectively to be accessed. It also provides the names of the associated files PARAMS.DAT and DEFINEF.DAT. As these assignments are set at run-time the user has the ability to rename any or all of these to meet his requirements. For example, the antenna configuration files could be placed in a sub-directory ANTS on drive D by setting

D:\CCIR\SG10\ANTS\ANT????.DAT

A maximum of 79 characters is permitted for these initialisation strings

2.2.7 Graphics input/output and required cards

The cursor-interactive input INP533A.EXE is usable with HGC, CGA and EGA graphics cards.

Two separate graphics output programs are provided: separate built-in and stand-alone graphics packages. For the former a file GRAPHO.EXE needs to be created by copying from HGCGRAPH.COM, CGAGRAPH.COM or EGAGRAPH.COM depending upon which card is employed(using EGAGRAPH.COM for VGA cards).

The stand-alone graphics can be employed with either a CGA, EGA or VGA display.

2.2.8 Running program REC533A

Before running program REC533A (or program REC533AX) it may be necessary to call program DGCALC(or DGCALCX) to pre-calculate values of directivity gain , etc, for the antenna used in the circuits of interest. This will be essential if an antenna of the Rec. 705 library is employed at either the transmitter or receiver and the corresponding ' nnnn.29F' antenna data file does not exist. See section 2.2.9 for further regarding programs DGCALC and DGCALX.

2.2.8.1 HD floppy disk drive systems

The program can be initiated by loading Disk 1, entering directory DIR533A, on a drive that is on-line and typing-

REC533A for systems with a math's co-processor fitted

or REC533AX for systems without such a device

2.2.8.2 Hard disk drives systems

It is recommended that the user copy Disk 1 on to a hard disk drive in order to minimise run times (see also section 2.2.2). A run can be started by placing that hard drive on-line , entering directory DIR533A or that containing program REC533A and typing

REC533A or REC533AX as described in 2.2.8.1 above

2.2.9 Running program DGCALC

Programs DGCALC and DGCALCX are run in a manner identical to programs REC533A and REC533AX, as described immediately above. Note that these programs are only used to determine modelling parameters directivity gain, and the elevation and azimuths of this parameter at the frequencies 2,3,....30 MHz for a given antenna.(see also section 3.1.4.1)

2.3 Running programs REC533A, DGCALC on non MS-DOS systems and re-compilation of source code

To run REC533A on other microcomputer systems, the user needs to read the source code versions of the programs and data base and then to generate corresponding object code. Provided the hardware is appropriate (Section 2.1) suitable software for these tasks should be available commercially. A further discussion of the compilation of source code is given in sections 6.2-6.4.

3. Input data

Five displays are provided

(i) An input file display listing the circuit data sub-sets of those circuits held in the directory. (Figure 1).

(ii) An edit display which lists all the parameters of a given circuit data set. (Figure 2).

(iii) A multiple run display which can be composed in order to perform successive calculations for particular circuit combinations. (This can also be used for a single circuit).(Figure 3)

(iv) Antenna specification displays which lists all the parameters of a given antenna for programs REC533A and DGCALC.(Figures 4, 5, respectively)

(v) Antenna directory files listing all antenna data sub-sets of those antennae held in the directory. (Figures 6 and 7).

The interelationship of these displays are shown in Figures 8 and 9

3.1 Parameters required to specify a circuit

Input data requirements are as indicated below. Units in which quantities are expressed are shown on the display when a given item is selected from the edit display.

3.1.1 Circuit/operational parameters

- (i) Latitude and longitude of the transmitter and receiver.
- (ii) Month, smoothed sunspot number and calendar year.
- (iii) Frequencies (maximum number 10).
- (iv) Universal Times.

3.1.2 System parameters

- (i) Transmitter power, minimum angle of elevation to be considered, transmitter antenna type and boresight bearing.
- (ii) Receiver bandwidth and required S/N ratio; percentage of the days of the month for which the required S/N ratio must be attained; receiver antenna type and bearing.

3.1.3 Noise background at receiver

Man-made noise environmental category or measured noise intensity.

3.1.4 Calculation of antenna gain and antenna types

3.1.4.1 Calculation of antenna gain

Antenna gain is evaluated, using the equations of CCIR Recommendation 705, at both the transmitter and the receiver for 10 different types of antenna(Table 1). Any antenna of each type can be specified by a set of parameters (design frequency, height of lowest element above the ground, etc.) enabling any practical antenna to be modelled for specified ground conditions. Gain is determined in terms of the directivity (or maximum) gain and the attenuation relative to this gain in any given direction. These two components of gain are computed separately.

For frequencies 2,3.,4 ..30 MHz directivity gain and the elevation and azimuth associated with this gain are evaluated using program DGCALC; these values are stored in files of the form 'nnnnANT.29F', where nnnn is a 3 or 4 digit antenna reference number. Each file is headed by the antenna reference number, type designation (section 3.1.4.2 and Table 1) and the type of ground at the antenna (section 3.3). Each file is a self-contained description of the antenna and ground configuration which is independent of ray-path frequencies and directions. For information regarding the deletion of antenna files for antenna 'nnnn' refer to section 2.2.3.

To compute these values is a lengthy task (typically 5 minutes on a 33 MHz 80486 DX PC) but one which needs only be undertaken once for each antenna. For antennae types which are combinations of dipoles, such as curtain arrays, directivity gain, etc., need only be calculated for those frequencies covering the useful operating range(0.7 - 1.4 D, where D is the design frequency). Other antenna types have their own limits (section 3.1.4.3)

Gains for the ray-path directions are determined separately, but relatively quickly, as part of the HF system calculations using program REC533A. At frequencies outside the useful operating range gain is set to -100 dB(see also section 4.1.7).

3.1.4.2 Antennae types

The types incorporated are:

(i) Curtain antennae:

Arrays of horizontal half-wave dipoles arranged vertically with passive reflecting elements of identical geometrical structure situated at a distance of $\lambda/4$ at the design frequency behind the main antenna are designated as xHR m/n/h/Sa/D, where λ is the wavelength. Multi-band curtain antenna have aperiodic screen reflectors while the dual-band types , which may be either centre or end-fed, employ tuned reflectors.

- x: descriptor to differentiate types where(A = multi-band antenna; C = centre fed, E = end-fed dual-band types respectively)
- m: number of half-wave dipoles in each row
- n: number of rows spaced half a wavelength apart one above the other
- h: height above the ground in wavelengths of the bottom row of dipoles
- Sa: S descriptor and angle of slew,a(degrees)
- D: design frequency(MHz)

(ii) Tropical antennae

Arrays of horizontal half-wave dipoles arranged horizontally, without a reflector, designated CT/m/n/h/Sa/D

- m: number of half-wave dipoles in each row
- n: number of parallel rows spaced half a wavelength apart
- h: height above the ground in wavelengths
- Sa: S descriptor and angle of slew,a(degrees)
- D: design frequency(MHz)

(iii) Horizontal log-periodic antennae

Tapered linear arrays of dipole elements of varying length designated LPH $N/L/h_1/h_N/L_1/L_N/Z$

- N: number of elements
- L: distance between the centres of the shortest and the longest elements(m)
- h_1: height of the shortest element(m)
- h_N: height of the longest element(m)
- L_1: length of the shortest element(m)
- L_N: length of the longest element(m)
- Z: impedance of the antenna internal feeder line(Ω)

(iv) Vertical log-periodic antennae

Tapered linear arrays of dipole elements of varying length designated
LPV $N/L/h_1/h_N/L_1/L_N/Z$

- N: number of elements
- L: distance between the centres of the shortest and the longest elements(m)
- h_1: height of the shortest element(m)
- h_N: height of the longest element(m)
- L_1: length of the shortest element(m)
- L_N: length of the longest element(m)
- Z: impedance of the antenna internal feeder line(Ω)

(v) Rhombic antennae, designation RH $l/\gamma/h$

- l: length of one side of the rhombus(m)
- γ: one half angle of the interior obtuse angle of rhombus(°)
- h: height of rhombus above ground(m)

(vi) Quadrant antennae, designation HQ n/h/D

- n: number of elements stacked above the other
- h: height of dipoles above the ground(λ)
- D: design frequency(MHz)

(vii) Cross-dipole antennae, designation HX h/D

- h: height of dipoles above the ground(λ)
- D: design frequency(MHz)

(viii) Vertical monopoles, designation VM $h/a_s/N/d$

- h: height of monopole(m)
- a_s: earth system radius(m)
- N: number of radial wires in the earth system
- d: diameter of the radial wires(mm)

For monopoles without a screen a_s, etc should be set to zero

(ix) Equivalent and other types

Currently, although curtain antennae with reflectors can be modelled the corresponding code for these types without reflectors is not directly available except for the case of one or more half-wave dipoles in a row. The gain and directive patterns of such antennae can be calculated using the formula for tropical antennae, setting n=1. Thus, for example, H /1/10.3 and 1/2/0.3 curtain arrays can be represented by a T 1/1/0.3 and T 2/1/0.3 tropical antennae respectively.

However, for curtain arrays without a reflector but with two dipoles in a single row the much simpler antenna gain package (Report 1062) will need to be used. Accordingly, gain computation for this antenna has been retained from an earlier related program along with the calculations for a vertical monopole over a perfectly conducting ground and for an isotropic antenna(Table 2). The latter could be usefully substituted for where, in practice, an antenna type not yet modelled such as a loop is employed. Using a vertical monopole over sea water is a reliable substitute for a vertical monopole over perfect ground.

3.1.4.3 Antenna frequency operating limits

For a reliable estimation of gain many of the antenna types, particularly, those that are combinations of dipoles, **should** only be operated within a specific frequency band. These limits are:

Recommendation 705 antennae:

(i) multi-band curtain antennae $0.7\ F_d \leq F \leq 1.4\ F_d$, MHz

(ii) dual-band curtain antennae $0.85\ F_d \leq F \leq 1.2\ F_d$, MHz

(iii) tropical,quadrant and cross-dipole antennae $0.85 \leq F_d \leq F\ 1.2\ F_d$, MHz

(iv) horizontal and vertical log-periodic antennae, usually 4- 30 MHz ,but also depends on the design (note maximum length of longest element = 75 metres)

(iv) horizontal rhombic antennae, usually 2- 30 MHz, but also depends on the design

(v) vertical monopole , $F \leq 104.94/Ht$, MHz , corresponding to $0.05\lambda < Ht < 0.35\lambda$, metres

where: F = operating frequency

F_d = design frequency

λ = operating frequency wavelength, metres

Ht = height of antenna, metres

Note that these broad limits may be further constrained for some types of antennae of certain dimensions. For example, for a horizontal log-periodic antenna the lower frequency limit may be above 4 MHz.

Report 1062 antennae:

There is no frequency dependence built into this simplified package. However, it is recommended the H 2/1/0.5 antenna be only employed for operating frequencies greater than 0.85 but less than 1.2 times the design frequency. Naturally, there are no frequency limits when employing the isotropic antenna.

3.1.4.4 Antenna reference number limitations

Antenna reference numbers are restricted according to category(Table 1). Thus, for example, numbers for multi-band-curtain array must in the range 100-199 and horizontal log periodic antennae are confined to the range 500-599. The upper limit for vertical monopoles is 1099. Running program DGCALC (and REC533) with an out-of-range number will cause unpredictable errors as the wrong section of the modelling code will be accessed. Antenna numbers are limited to 0-2 for antennae from Rep. 1062.

Table 1 Examples of the different antenna types(Rec. 705) over medium dry ground (ε_r=15, σ =0.001 Rec 527) for a design frequency, where appropriate, of 10 MHz

Antenna number	Type	Operat. Freq. (MHz)	Freq. ratio F_R	Slew angle, s(°)	Gain (dBi)	Elev. of beam max.(°)
Curtain antennae(multi-band half-wave dipole array with aperiodic screen reflector):						
100	AHR 2/2/0.5/S0/10	10	1	0	15.7	17
101	AHR 2/2/0.5/S15/10	10	1	15	15.8	17
102	AHR 2/2/0.5/S-15/10	10	1	-15	15.8	17
103	AHR 4/3/0.5/S0/10	10	1	0	19.9	12
104	AHR 4/4/0.5/S0/10	7	0.7	0	18.3	13
105	AHR 4/4/0.5/S15/10	7	0.7	15	18.3	13
106	AHR 4/4/0.5/S30/10	7	0.7	30	18.2	13
107	AHR 4/4/0.5/S0/10	10	1	0	21.0	9
108	AHR 4/4/0.5/S15/10	10	1	15	20.9	9
109	AHR 4/4/0.5/S30/10	10	1	30	20.6	9
110	AHR 4/4/0.5/S0/10	14	1.4	0	23.1	7
111	AHR 4/4/0.5/S15/10	14	1.4	15	23.0	7
112	AHR 4/4/0.5/S30/10	14	1.4	30	22.1	7
113	AHR 4/4.1.0/S0/10	10	1	0	21.9	7
Curtain antennae(dual-band centre-feed half-wave dipole array with tuned reflector):						
200	CHR 2/1/0.5/S0/10	10	1	0	12.2	28
201	CHR 2/2/0.5/S0/10	10	1	0	15.3	17
202	CHR 2/2/0.5/S15/10	10	1	15	15.2	17
Curtain antennae (dual-band end-feed half-wave dipole array with tuned reflector):						
300	EHR 2/1/0.5/S0/10	10	1	0	12.2	28
301	EHR 2/2/0.5/S0/10	10	1	0	15.3	17
302	EHR 2/2/0.5/S15/10	10	1	15	15.3	17
Tropical antennae:						
400	CT 1/2/0.3/S0/10	10	1	0	7.2	90
401	CT 2/2/0.3/S0/10	10	1	0	9	90
402	CT 2/2/0.3/S15/10	10	1	15	9	90
Horizontal log-periodic antennae:						
500	LPH 18/35/30/30/3/26/89	10	-	-	11.1	14
Vertical log-periodic antennae:						
600	LPV 18/45/3/17/6/34/220	10	-	-	3.7	18
Rhombic antennae:						
700	RH 90/55/15	10	-	-	13.9	15
Quadrant antennae:						
800	HQ 1/0.3/10	10	-	-	4.9	55
Cross-dipole antennae:						
900	HX 0.3/10	10	-	-	5.3	55
Vertical monopoles:						
1000	VM 12.5/12.5/120/3	10	-	-	1.6	23

Table 2 Antenna types(Rep. 1062)

Antenna number	Type	Gain (dBi)	Elevation of beam maximum (°)
0	Isotropic	0	-
1	H 2/1/0.5	11	28
2	Vertical	4	27

3.1.5 Required output option

Five separate printout forms are provided together with one built-in graphics output.

The stand-alone graphics program is run as a separate entity and is not directly accessable from the input displays. For further information see section 4.2.

3.2 Cursor-interactive input

Five displays, as indicated above are provided

A selection of operations as described below, is available with these displays.

On loading REC533A a Turbo Pascal program (INP533A.EXE) is called and the input file display is viewed(see Figure 1).

Calculations can be performed in input file display mode, multiple circuit run mode or edit display mode.

3.2.1 Input file display mode

With the cursor keys an individual circuit can be highlighted and then using the function keys F1-F8 various operations performed on it.

Cursor highlighting actions are as follows:

Up arrow: moves cursor upwards one circuit in list
Down arrow: moves cursor downwards one circuit
Page up: moves cursor to first circuit on previous page
Page down: moves cursor to first circuit on next page
Home: moves cursor to first circuit in directory
End: moves cursor to last circuit in directory
Pressing the RETURN key also moves the cursor downwards one entry.

The designation of the function keys for individual circuit operation is:

F1. Performs calculations and sends output to a printer
F2. Performs calculations and sends output to the screen
F3. Performs calculations and sends output to a disk file (REC533A.OUT)
F4. (or ENTER) Enters edit display and run mode
F5. Enters multiple circuit assembly and run mode
F6. Deletes the circuit data set from the directory
F7. Renumbers circuit data sets
F8. (or ESC)Quits program

3.2.2 Multiple-circuit assembly and run mode

This facility, which is entered by pressing key F5, provides batch running of up to 50 circuits at a time. Batches are assembled and run. For assembly, circuits included in the directory are reviewed by placing the cursor over the circuit name using the arrow keys. A particular circuit is selected by pressing key F4 (in which case a highlighted number appears next to the circuit name and the cursor moves automatically to the next circuit of the directory). The running total of number of circuits selected appears in the top right-hand corner of the screen.

The designation of the function keys for multiple circuit selection and running is:

F1. Runs multiple circuits and sends output to a printer
F2. Runs multiple circuits and sends output to the screen
F3. Runs multiple circuits and sends output to a disk file (REC533A.OUT)
F4. Selects a circuit for a multiple run
F5. Quits multiple run selection facility

3.2.3 Edit display and run mode

After pressing the F4 key whilst in the input file display a new screen display appears(Figure 2) giving in the top half a listing of parameters for the previously highlighted circuit. The cursor appears highlighting the first parameter (the Method).

Parameters are reviewed by using the arrow key commands: These are as follows:

Up arrow: moves upwards one parameter
Down arrow: moves downwards one parameter
Left arrow: moves back one parameter in list
Right arrow: moves onto next parameter in list

Every time the cursor is moved a corresponding message is displayed towards the bottom half of the screen, explaining what the parameter is and advising the user regarding the limits imposed and units to be used. To change a parameter just move the cursor over it and type in the new value, followed by a 'RETURN'. A small message appears in mid-screen to advise of invalid entries, in which case enter again until the value is valid.

The backspace key can be used to delete a character.

In the edit display and run mode the function keys are employed as follows:

F1. Performs calculations for viewed circuit and sends output to a printer
F2. Performs calculations for viewed circuit and sends output to the screen
F3. Performs calculations for viewed circuit and sends output to a disk file(REC533A.OUT)
F4. Stores edited circuit data set in input file directory
F5. (or ESC)Quits edit mode and returns to input file display mode

3.2.4 Antenna specification display

When running program REC533A this display(Figure 4) is accessed from the edit display by moving the cursor to the transmitter or receiver antenna parameter, TXANT or RXANT respectively, and then pressing 'RETURN'. The number following this parameter uniquely identifies a specific antenna. In the antenna specification display all the parameters pertinent to the selected antenna are presented on one or more pages as required. .

On loading program DGCALC the antenna directory display is entered directly(section 3.2.5). By using the up/down arrow cursor keys the antenna of interest can be highlighted and then loaded (Figure 5) by pressing 'RETURN' (or 'ESC'). New antenna designs can be conveniently generated by editing an existing specification of the same antenna type. DGCALC cannot be used for HF prediction computations and thus the circuit and edit displays are not required.

Note that while this display can be viewed using program REC533A specification parameters can only be changed when running program DGCALC. On the other hand, DGCALC is be only used to view an existing or generate a new antenna design which could subsequently be accessed by program REC533A.

Antenna specification parameters are reviewed by using the arrow key commands: These are as follows:

Up arrow: moves upwards one parameter
Down arrow: moves downwards one parameter
Also the RETURN key moves onto next parameter in list.

Every time the cursor is moved a corresponding message is displayed towards the bottom half of the screen, explaining what the parameter is and advising the user regarding the limits imposed and units to be used. To change a parameter just move the cursor over it and type in the new value, followed by a 'RETURN'. A small message appears in mid-screen to advise of invalid entries, in which case enter again until the value is valid.

The backspace key can be used to delete a character.

In this display the escape(ESC) and function keys are employed as follows:

ESC Exit and return to edit mode display (Program REC533A)
ESC Exit program (Program DGCALC)
F1. Enters antenna directory

With program DGCALC only there is an important further option:

F9. Undertakes long evaluation

The long evaluation is the background mode calculation of directivity gain, and the elevation and azimuth at this maximum gain. When calculations are completed, values of these parameters, at the design frequency shown in the display, are passed back to the antenna specification file to become part of an updated display. For those antennae for which there is no design frequency directivity gain is given for the quoted operating frequency. However, the bulk of the computation in this mode are to determine directivity gain, etc., at the frequencies 2,3,4...30 MHz (or over the normal frequency operating range) the results of which are stored in files nnnnANT.29F, where 'nnnn' is the antenna reference number. This file is then used by REC533A to evaluate the attenuation along the path azimuths.

Note that the directivity gain and its associated parameters are all dependent on the values of all the other parameters of the specification with the exception of reference number, type and description. Should a user need to modify an antenna then it is advisable to request a long evaluation Failure to do this may mean that no corresponding new 'nnnANT.29F' file will be available for use by program REC533A. If the reference number is changed then a long evaluation is also desirable for this reason.

On leaving this screen (by typing ESC or F1), where an antenna has been modified the user will be asked whether the new antenna specification is to saved. If an existing specification has been modified (i.e. an existing antenna reference number was retained) the user will be also asked if the old specification is to be replaced by the new.

There are two operational parameters that form part of the antenna specification screen and which can be viewed at the end of the display. They are (i) style of evaluation and (ii) the computational status. The former needs to be set to unity for a long evaluation(initiated by pressing F9). However, changes to parameters can be made without a long evaluation by setting this 'style of evaluation' parameter to zero and then pressing F9. This could be useful for editing of the type or description text strings. Appropriate messages are sent to the screen in both cases. However, if subsequently a long evaluation if required for this antenna the user should check on the status of the parameter. The computation status parameter is set to unity when calculations are complete and zero otherwise.

It is also possible to modify an antenna by using values of directivity gain , elevation and azimuth at this maximum gain obtained by other means such by using the NEC or MINNEC codes. Here values of this gain, etc. replace those in the display (by setting the style of evaluation to zero, and inserting these values for frequencies 2,3...30 MHz into an appropriate 'nnnnANT.29F' file).

3.2.5 Antenna directory display

This display(Figures 5 and 7), which contains selected items from all of the available antenna specifications, is accessed from the antenna specification display using the F1 key. This display has two windows as follows (i) the type (of antenna) mode (i.e. curtain , horizontal log-periodic etc.) and (ii) the (physical) description mode(AHR 4/4.0.5/S0/10, etc.). The F1 key can be used to toggle between them. In each mode an individual antenna can be highlighted with the cursor keys.

In either display the following quantities are shown:

(i) Op-Freq,-the input operating frequency

(ii) DG, computed directivity gain at (i)

(iii) El and Az, the elevation and azimuth of the directivity (maximum) gain

(iv) Ground, the ground type (0-4 of Table 3)

Cursor highlighting actions are as follows:

Up arrow: moves cursor upwards one antenna in list
Down arrow: moves cursor downwards one antenna
Page up: moves cursor to first antenna on previous page
Page down: moves cursor to first antenna on next page

In this display the following keys are employed as follows:

ESC Exit and return to antenna specification display
RETURN. Loads the highlighted antenna updating the edit display(Program REC533A)
RETURN. Return to Antenna specification display (Program DGCALC)

In program REC533A when an antenna is loaded it replaces that highlighted in the edit display which can be returned to (via the antenna specification) by pressing 'ESC' twice. Exit to DOS(via the antenna specification display) from program DGCALC is achieved by typing 'ESC' twice again .

3.3 Types of ground options(Recommendation 527)

Antenna gain for antennae number 100 and upwards (Table 1) can be evaluated for 4 types of ground(Table 3) or using user-specified values of dielectric constant(relative permitivity), ε_r and ground conductivity, σ.

Table 3 Types of ground (Rec. 527)

Ground option	dielectric constant, ε_r	ground conductivity,σ ,S/m
0	user specified	user specified
1, very dry ground	3	0.0001
2, medium dry ground	15	0.001
3, wet ground	30	0.01
4, sea water	80	5.0

3.4 Transmitter and receiver co-ordinate representations

The compass pointing (geographical N, E, S, W) may be immediately before or after the numerical co-ordinate or, following IFRB practice, between the integer and fractional parts. Examples of these three forms are N51.56,51.56N and 51N56 respectively. The quantities N52 and 52N are interpreted as 52 degrees north. These options are additional to the ability to input co-ordinates either in decimal degrees or degrees and minutes.

4 Output data

Five printout options and one built-in graphics output option are provided embedded in the program. The stand-alone graphics package yields a further six separate output options.

4.1 Embedded output options

With each of the options indicated in Table 4 data are presented for each selected UT and frequency. Field strengths, signal/noise ratios and basic MUFs are monthly median values except with Methods 2 and 3 where the predicted signal/noise ratio is for a user specified required percentage of the days of the month.

Table 4 Embedded output options

Method	Parameters
1	skywave field strength
2	signal/noise ratio
3	frequencies with monthly median signal/noise ratio exceeding required value
4	best operating frequency from those of an input list
5	graphical presentation of the times for which user specified frequencies are likely to propagate
6	extended output

The following 4 lines of header information are common to all outputs(e.g. see Figure 10).

- line 1 : output method : = 1, 2, 3, 4, 5 or 6, program version
- line 2 : month, year, smoothed sunspot number
- line 3 : circuit identification : transmitter and receiver names, headers for line 4 , short or long great path indication(SP or LP respectively)
- line 4 : transmitter and receiver geographical co-ordinates, transmitter-to-receiver and receiver-to-transmitter azimuths, path lengths nautical miles and in km

In addition there are:

- line 5 : minimum angle of elevation (degrees), transmitter and receiver antenna bearings, transmitter power (this line is not available with method 5)
- line 6 : transmitter antenna type and the useful frequency operating range; receiver antenna type and the useful frequency operating range (this line is not available with method 5)
- line 7 : percentage of days (S/N%)for which the lowest usable frequency (LUF) is to be computed (fixed at 50%), man-made noise environmental category 1-4 (Table 5) or user specified noise power in dBW at 3 MHz in a 1 Hz bandwidth , receiver bandwidth in Hz, and required signal/noise ratio (line 7 is not available with methods 4 and 5)

For method 5 line 5 contains:

- line 5 : minimum angle of elevation (degrees), transmitter power, transmitter and receiver antenna types

Table 5 Man-made noise environmental categories

Category	Description
1	business area (-140.4 dBW)
2	residential area (-144.7 dBW)
3	rural area (-150.0 dBW)
4	quiet-rural area (-163.6 dBW)

4.1.1 Method 1: RSS(root sum square) median skywave field strength

For each selected UT the following are tabulated

(i) MUF, basic maximum usable frequency (MHz)
(ii) RSS median field strength of the strongest modes in dB above 1μV/m for the MUF and for the different selected frequencies
(iii) LUF, lowest usable frequency (MHz).(see section 4.1.7 below)
(iv) FOT, optimum working frequency (MHz)
(v) OPMUF, operational MUF (MHz)

An example of this method is given in Figure 10.

4.1.2 Method 2: Signal/noise ratio for a required percentage of time

The format is identical to 4.1.1 except signal/noise ratios are given for the required percentage of time (between 10-90% of the month). Examples of this method are given in Figures 11 and 12.

4.1.3 Method 3: When a required signal/noise ratio is achieved

When the required signal/noise ratio, for the required percentage of days of the month, is achieved (or exceeded) this is shown by a *; otherwise there is a blank space.

An example of this method is given in Figure 13.

4.1.4 Method 4: Prediction of best operating frequency

The frequency from an input list closest to the FOT(lower decile of the operational MUF) is tabulated providing the LUF is less than the operational MUF.

An example of this output is shown in Figure 14.

4.1.5 Method 5: Built-in graphical presentation of LUF and operational MUF

This method provides a graphical presentation over 24-hours UT of the operational MUF, LUF and those frequencies from an input list, up to a maximum of 3 at a given hour, for which propagation is possible. Where more than 3 frequencies can propagate those closest to the FOT are given. Typing 'P' in response to the question 'Press any key...' enables this output to be printed on an on-line dot matrix printer. For other printers use the 'Shift-PrtSc' keys in conjunction with either the DOS command 'graphics [type]' or screen dump software. Any other response results either in calculations for the next circuit or a return to the input directory. An example of this method is illustrated in Figure 15.

4.1.6 Method 6: Extended output

In this tabulation (Figures 16 and 17) following the standard header information at each UT are:

- line 1 : FREQ : Universal Time (UT)
basic maximum usable frequency, MUF (MHz)
input frequency list (MHz)
lowest usable frequency, LUF (MHz)
optimum working frequency, FOT (MHz)
operational MUF, OPMUF (MHz)

For the basic MUF and the selected frequencies those entries are followed by:
- line 2 : MODE : Number of hops and propagation mode
- line 3 : ANGLE : Angle of elevation (degrees)
- line 4 : DBU : RSS median field strengths at the receiver (dB above 1μV/m)
- line 5 : S/N : Signal/noise ratios (dB)
- line 6 : FS/N :Probability that the required signal/noise ratio is achieved.('reliability')

Note the signal/noise ratio for this method is always the monthly median (or 50%) value. The option of predicting this quantity for any required percentage of time (between 10 and 90%) is only available with methods 2 and 3 as Recommendation 533 specifies reliability in terms of monthly median signal and noise powers.

4.1.7 Computation of RSS median field strength, signal/noise ratio, reliability and LUF

As antenna gain is set separately to -100 dB for frequencies which are outside the operating limits at both the transmit and receive antennae these parameters are accurately calculated only for frequencies within the combined bounds though field strength is only restricted by the transmit antenna limits. LUF, the lowest frequency at which a required monthly median signal-to-noise ratio is achieved, would normally be within the these limits or set equal to the operational MUF.

The LUF is evaluated in terms of the monthly median signal and noise powers even where, for method 2 or 3, signal-to-noise ratio is determined for other than 50% of the time

4.2 Stand-alone graphics output package

The graphics program CGRAPH, which is separate from the built-in graphics of section 4.1.5, requires as input the output data (CGRAPH.OUT) from Method 2 and permits separate colour presentation of the following quantities. Printed copies can be obtained using the 'Shift-PrtSc' keys in conjunction with either the DOS command 'graphics [type]' or screen dump software.

4.2.1 Circuit characteristics

The path and operating parameters of a single circuit are displayed as shown in Figure 18.

4.2.2 Basic MUF, operational MUF, FOT and LUF

These frequencies are displayed for the hours 00-23 UT. An example is given in Figure 19.

4.2.3 Field strength, noise power and signal/noise ratio

Histograms of these parameters are shown

(i) for the hours 00-23 UT for a frequency selected from an input list (Figure 20).
(ii) for all frequencies of the input list at a given UT (Figure 21).

4.2.4 Modes and angles of elevation

Histograms of these quantities are illustrated:

(i) for the hours 00-23 UT for a frequency selected from an input list (Figure 22)
(ii) for all frequencies of the input list at a specified UT (Figure 23).

5. Reference ionospheric numerical data

5.1 Content

Use is made of CCIR Data Disk Set A, (Resolution 63, see Table 6 below). (Dick, 1990)

Table 6: Contents of Data Disk Set A

	DATA
1.	foF2 (Oslo coefficients)
2.	M(3000)F2
3.	1 MHz atmospheric noise power (LT representation, Rec. 372
4.	Atmospheric noise power prediction uncertainties and decile deviations
5.	Frequency dependence of 1 MHz atmospheric noise power
6.	Excess system loss median and standard deviations

5.2 File structure

There is a separate binary file for each monthly set of ionospheric or associated data. The total storage requirements are:

Number of files	12
Number of values	84312
Storage (bytes)	342792
Storage (Mbytes)	0.33

For each month this disk set contains the following arrays corresponding to the items 1-6 of Table 6.

(1) IFA(10,2), XF2COF(13,76,2)
(2) IMA(10,2), XFM3CF(9,49,2)
(3) FAKP(29,16,6), FAKABP(2,6)
(4) DUD(5,12,5)
(5) FAM(14,12)
(6) SYS(9,16,6)

6. Source Code

6.1 Language selection

Prospero Fortran 77 was used for the writing of program REC533A as suitable code segments in that language already existed. However, Turbo Pascal 4 and Quick Basic 4 were found to be more suitable for the generation of the cursor-interactive input and the stand-alone graphics packages respectively.

6.2 Compilation/implementation on other systems

To optimise the running of program REC533A both the cursor-interactive input system and the built-in graphics (only available as object code) have been integrated within it using calls to the non-standard library subroutine EXECPG.(section 6.3). Equivalent code to compile and run the program using Microsoft Fortran is given below in section 6.4. However, for users who wish to compile REC533A but who do not have access to either of these Fortran 77 compilers or to an equivalent subroutine, difficulties may arise. There are two solutions as follows with both involving re-compilation of the Fortran source code:-

(i) program INP533A can be run in the 'stand alone' mode to produce a verified file of intermediate input data USERF2.OUT which can be read directly by subroutine USERF2. The built-in graphics can also be run separately to access file MICROP2.GRP generated by program REC533A.

(ii) where REC533A is run with the cursor-interactive input, the intermediate file is further processed to generate a formatted file REC533A.INP The resulting file can be read using code provided in the main routine (following statement No. 94, after setting INX=0). The options of sending the output file to a printer (default or 'PRN'), to the console ('CON') or to a named file are also provided.

Unfortunately, binary formats are not standardised between Fortran compilers. Thus, the reference numerical data REP89401.BIN etc. may need to be regenerated from the source data. These are available on Disks 2 and 3 together with the conversion program CONV2A.FOR as described in section 2.2.1.

Equivalents of the date and time routines (DATE and TIME) will also be required for re-compilation (for Microft Fortran see section 6.4)

The operation of the stand alone graphics package is, of course, unaffected.

6.3 EXECPG library function

This Prospero Fortran 77 extension to the standard language enables an object code 'child program' (with extension .EXE or .COM) to be loaded from program REC533A or other Fortran program.

The two 'child programs' involved are the object code of the Turbo Pascal 4 input generator and the Turbo Pascal 3 built-in graphics output.

6.4 Compilation under Microsoft Fortran 77

The following code fragments can be used to replace function EXECPG to call the Turbo Pascal input generator and graphics output:

```
INTEGER*2 SYSTEM

ISYS = SYSTEM('INP533A.EXE'C)      or  ISYS = SYSTEM('GRAPHO.EXE'C)

IF(ISYS.EQ.-1) STOP
```

The following should be placed at the head of the main routine:

```
$INCLUDE: 'EXEC.FI'
```

EXEC.FI can be found in directory DEMOS on the Microsoft Fortran disk source code (see also Microsoft Advanced Topics, p 87).

Microsoft Fortran date and time procedures GETDAT and GETTIM can be used in place of the Prospero Fortran equivalents though the arguments will need to be declared integer*2

7. References

Dick, M.I. (1990), 'Description of Disks of CCIR Numerical Ionospheric Reference Data'. CCIR Secretariat, Geneva.

Rossi, G. (1991),'Calculation Of Antenna Patterns For Hf Broadcasting Planning', Telecommunication Journal, 58, X/1991

8. Acknowledgements

Use is made of computer code extracted from other CCIR programs made available by the Secretariat. The Fortran code for Rec. 705 antenna modelling was translated by K. Hunt of the EBU from the Basic code written by G. Rossi of the CCIR Secretariat.

This handbook and the programs described therein were produced by Drafting Groups 2 and 9 of CCIR Working Party 6A. The participants in these DG were M I Dick(Chairman, DG2 and 9) and S M Harrison(DG2), RAL,Chilton, Oxon, UK; G Hand(DG2 and 9), ITS, Boulder, USA; K Hunt(DG2 and 9), EBU, Geneva, Switzerland; D B Ross(DG2), CRC,Ottawa,Canada; A-M Bourdilla(DG9), CNET, France; M Peres(DG9), LIARA,Argentina and K Edwards(DG9) , Consultant, UK (ex BBC) who also provided valuable advice on frequency operating limits for antennae to DG2. Extensive advice on the text of this handbook was also obtained from P A Bradley, Chairman of WP-6A

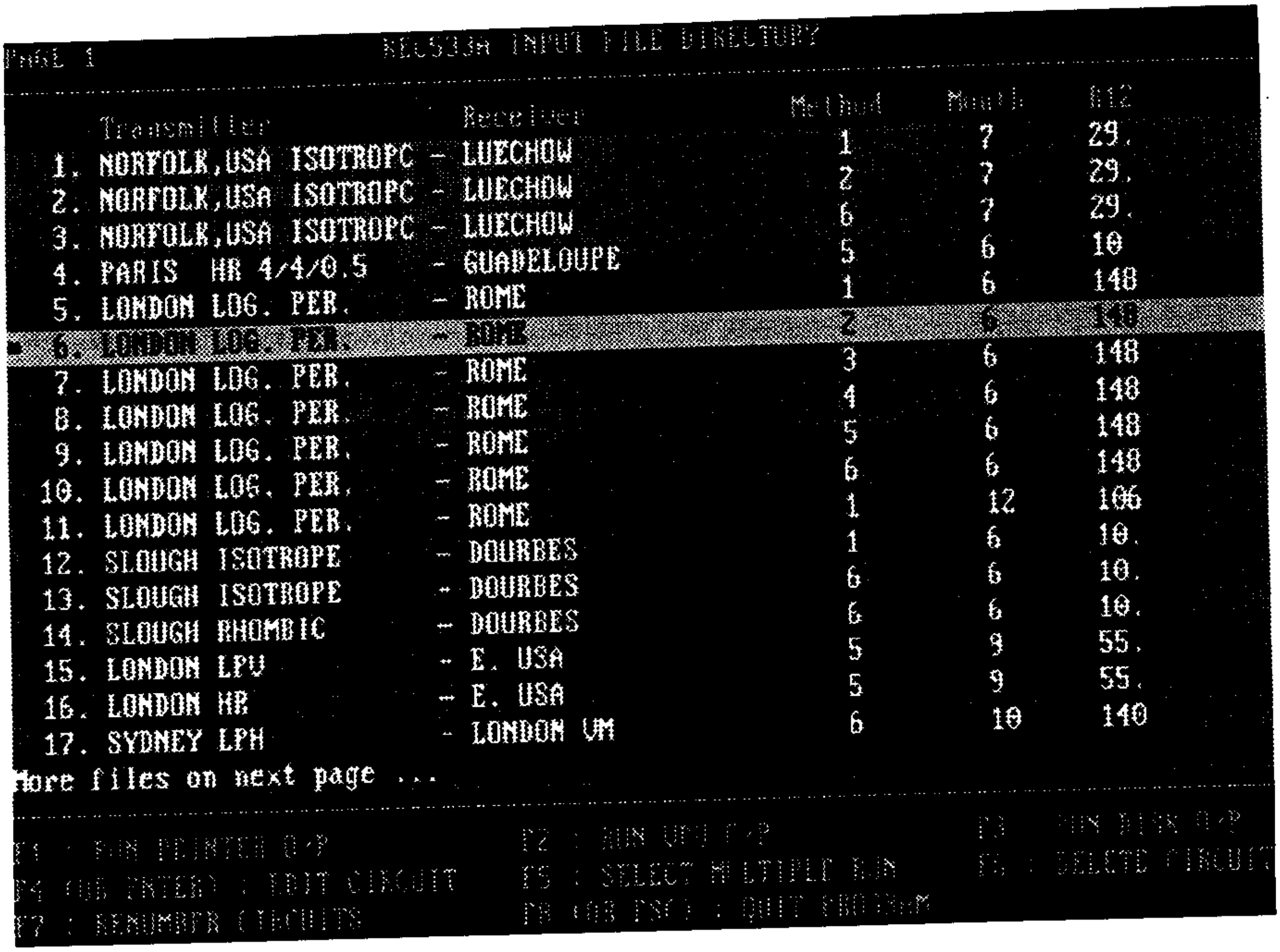


Figure 1: Example of REC533A input file display

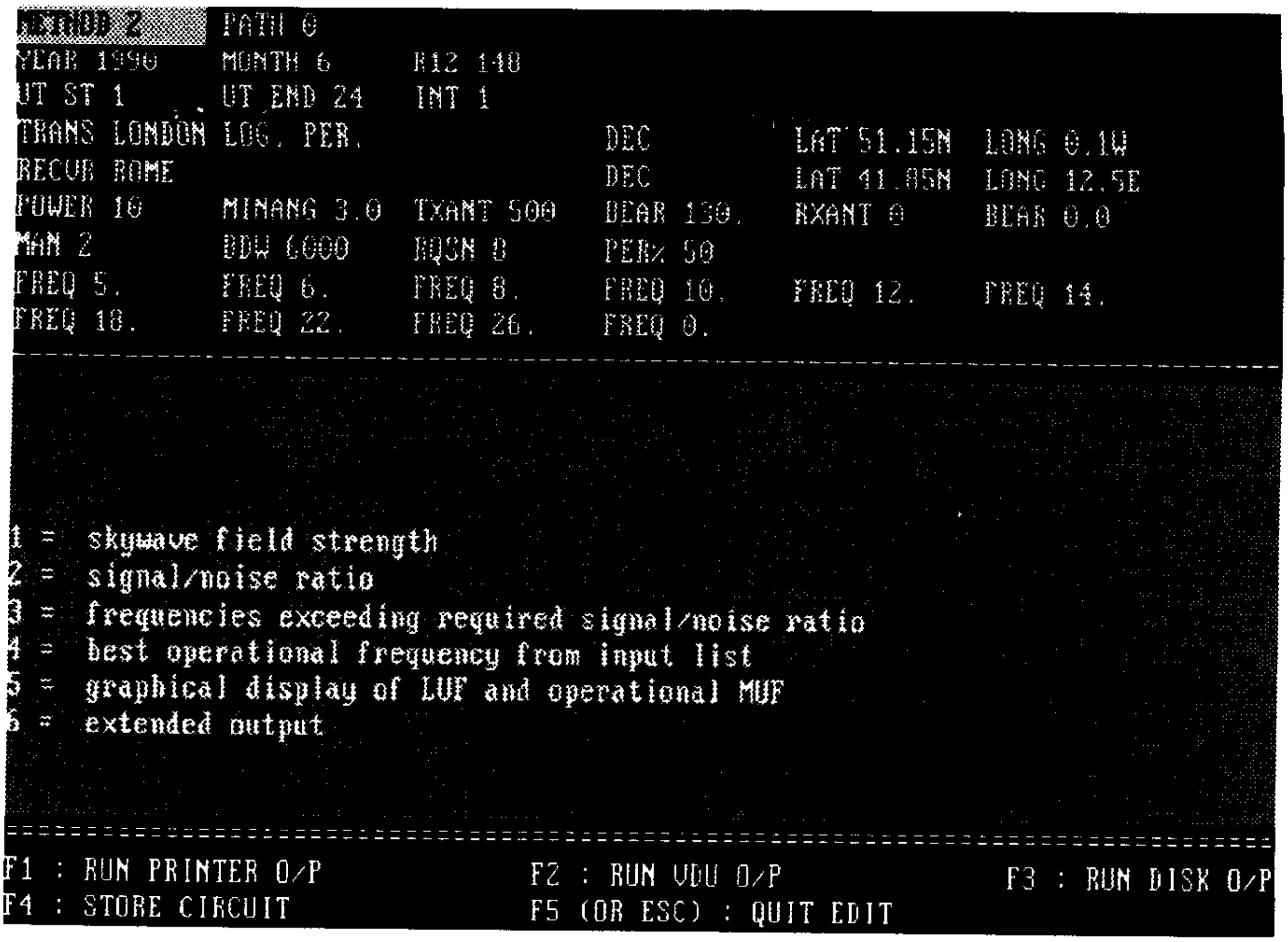


Figure 2: Example of edit display

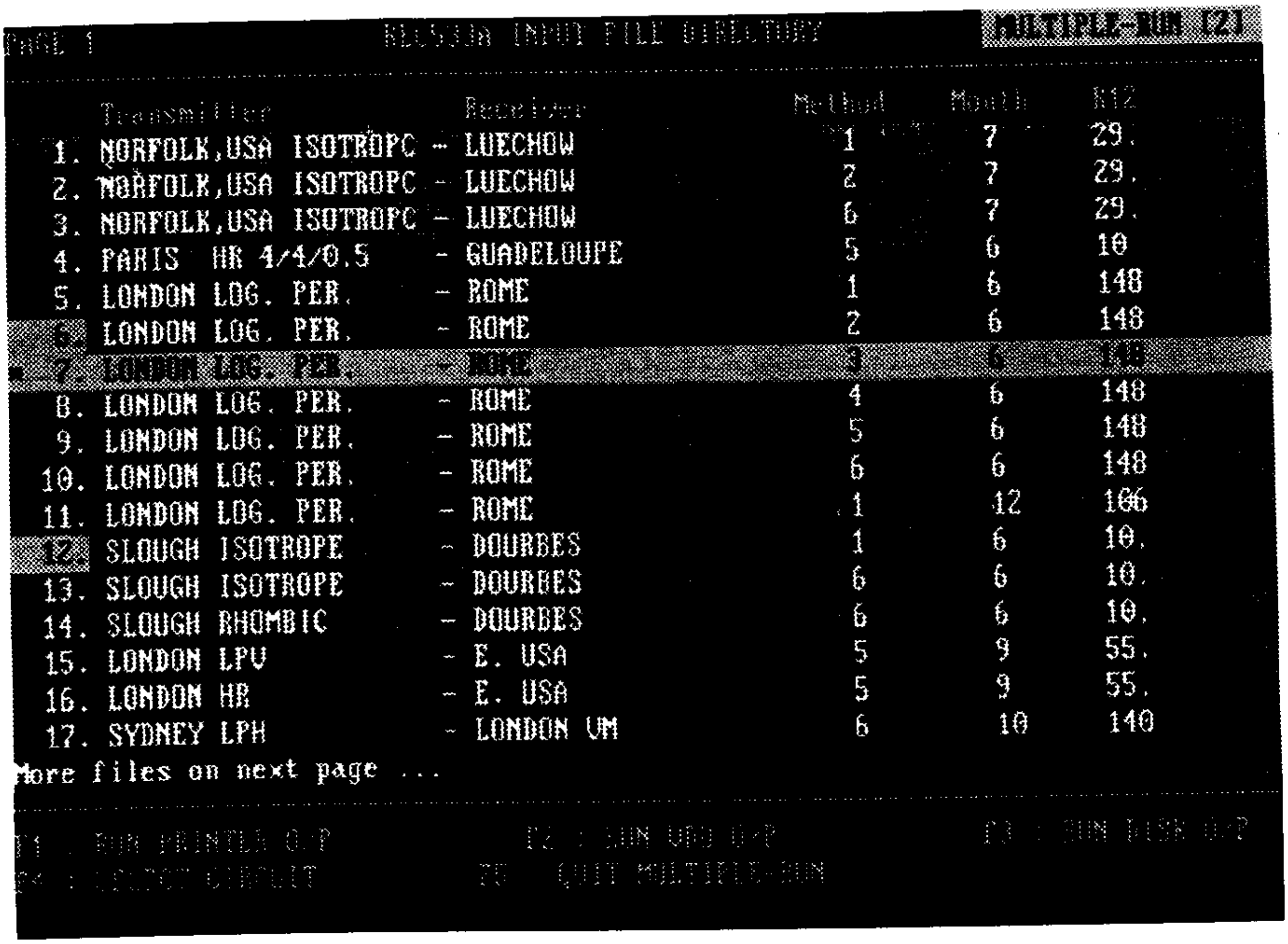
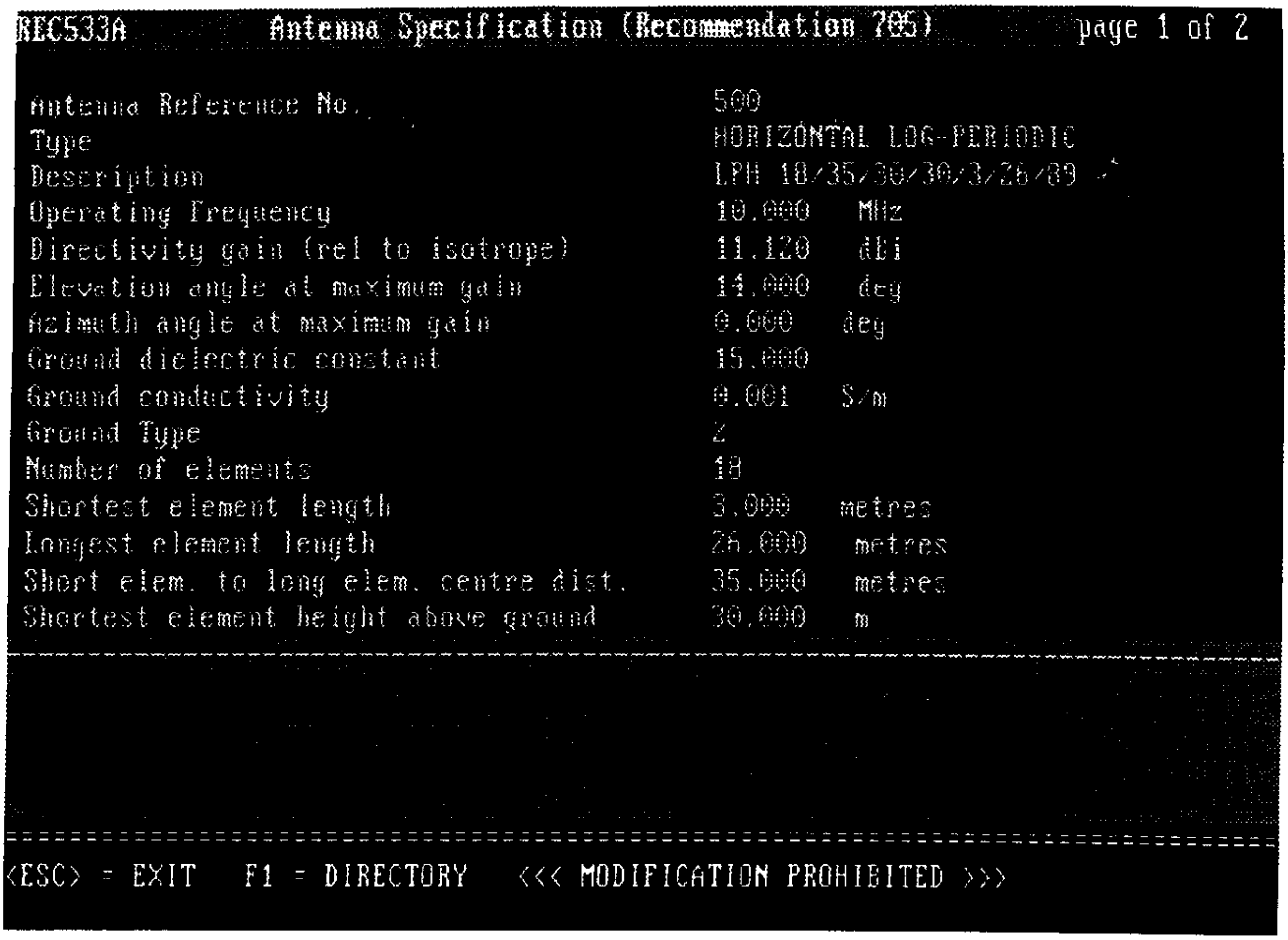


Figure 3: Example of a multiple run display



REC533A Antenna Specification (Recommendation 705) page 1 of 2

Antenna Reference No.	500
Type	HORIZONTAL LOG-PERIODIC
Description	LPH 18/35/30/30/3/26/89
Operating Frequency	10.000 MHz
Directivity gain (rel to isotrope)	11.120 dBi
Elevation angle at maximum gain	14.000 deg
Azimuth angle at maximum gain	0.000 deg
Ground dielectric constant	15.000
Ground conductivity	0.001 S/m
Ground Type	2
Number of elements	18
Shortest element length	3.000 metres
Longest element length	26.000 metres
Short elem. to long elem. centre dist.	35.000 metres
Shortest element height above ground	30.000 m

<ESC> = EXIT F1 = DIRECTORY <<< MODIFICATION PROHIBITED >>>

Figure 4: Example of an antenna specification display (program REC533A)

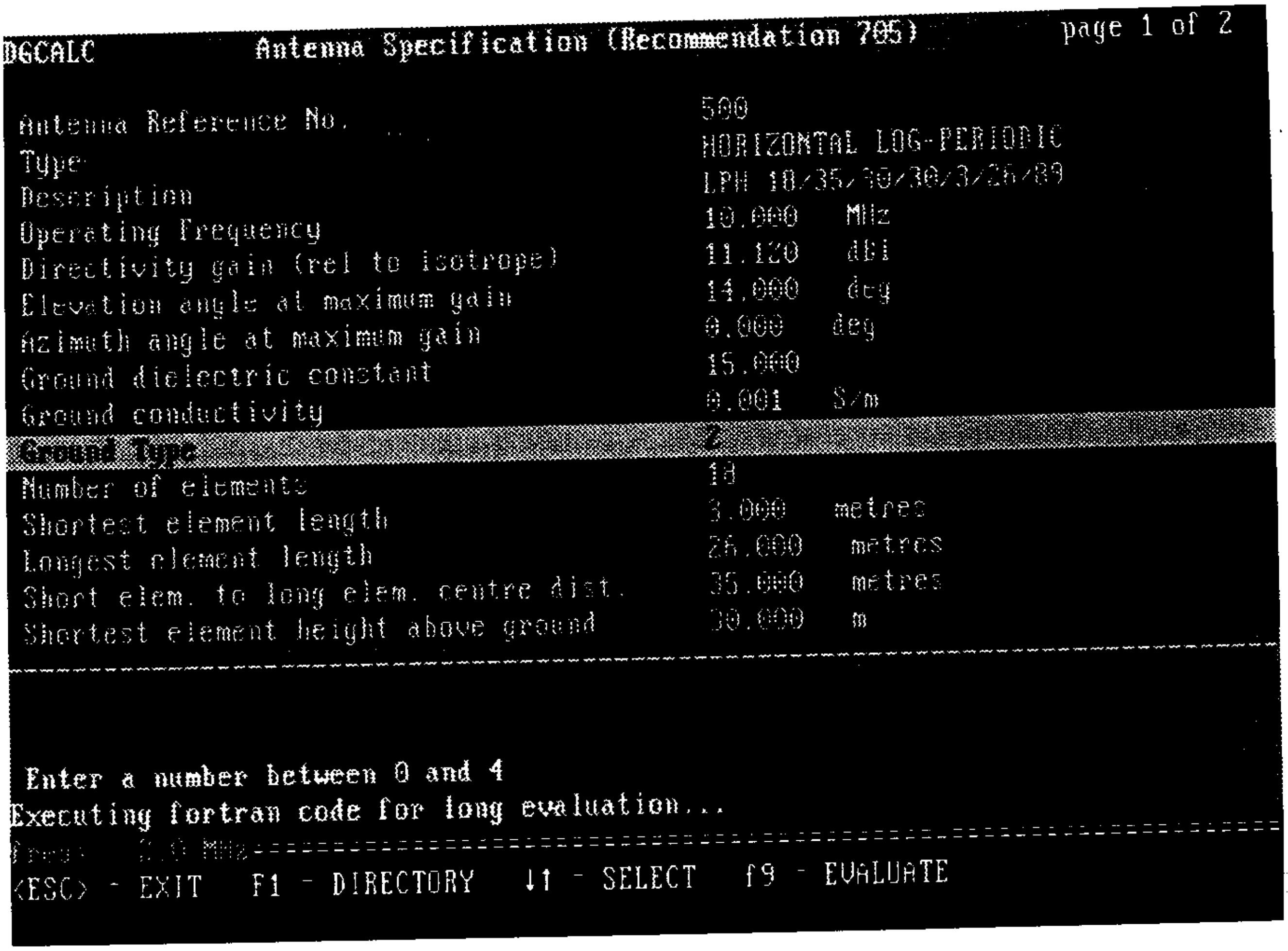


Figure 5: Example of an antenna specification display (program DGCALC)

REC533A ------ ANTENNA DIRECTORY------ Page 1 of 3

Ref	Type (f1 for Description)	Op-Freq	DG	El	Az	Ground
0	ISOTROPIC	10.0	0.0	0.0	0.0	1
1	CURTAIN ARRAY NO REFL. H 2/1/0.5	10.0	11.0	28.0	0.0	1
2	VERTICAL MONOPOLE OVER PERFECT GROUND	10.0	4.0	47.0	0.0	1
100	MULTIBAND APER.REF. ARRAY	10.0	15.7	17.0	0.0	2
101	MULTIBAND APER.REF. ARRAY	10.0	15.8	17.0	9.0	2
102	MULTIBAND APER.REF. ARRAY	10.0	15.8	17.0	351.0	2
103	MULTIBAND APER.REF. ARRAY	10.0	19.9	17.0	0.0	2
104	MULTIBAND APER.REF. ARRAY	7.0	18.3	13.0	0.0	2
105	MULTIBAND APER.REF. ARRAY	7.0	18.3	13.0	11.0	2
106	MULTIBAND APER.REF. ARRAY	7.0	18.2	13.0	22.0	2
107	MULTIBAND APER.REF. ARRAY	10.0	21.0	9.0	0.0	2
108	MULTIBAND APER.REF. ARRAY	10.0	20.9	9.0	13.0	2
109	MULTIBAND APER.REF. ARRAY	10.0	20.6	9.0	25.0	2
110	MULTIBAND APER.REF. ARRAY	14.0	23.1	7.0	0.0	2
111	MULTIBAND APER.REF. ARRAY	14.0	23.0	7.0	15.0	2
112	MULTIBAND APER.REF. ARRAY	14.0	22.1	7.0	28.0	2
113	MULTIBAND APER.REF. ARRAY	10.0	21.9	7.0	0.0	2
114	MULTIBAND APER.REF. ARRAY	10.0	14.9	20.0	0.0	0

<ESC> = EXIT ↓↑ = SELECT <RETURN> = LOAD ANT. FILE = ANT103.DAT

Figure 6: Example of an antenna directory display (type mode)

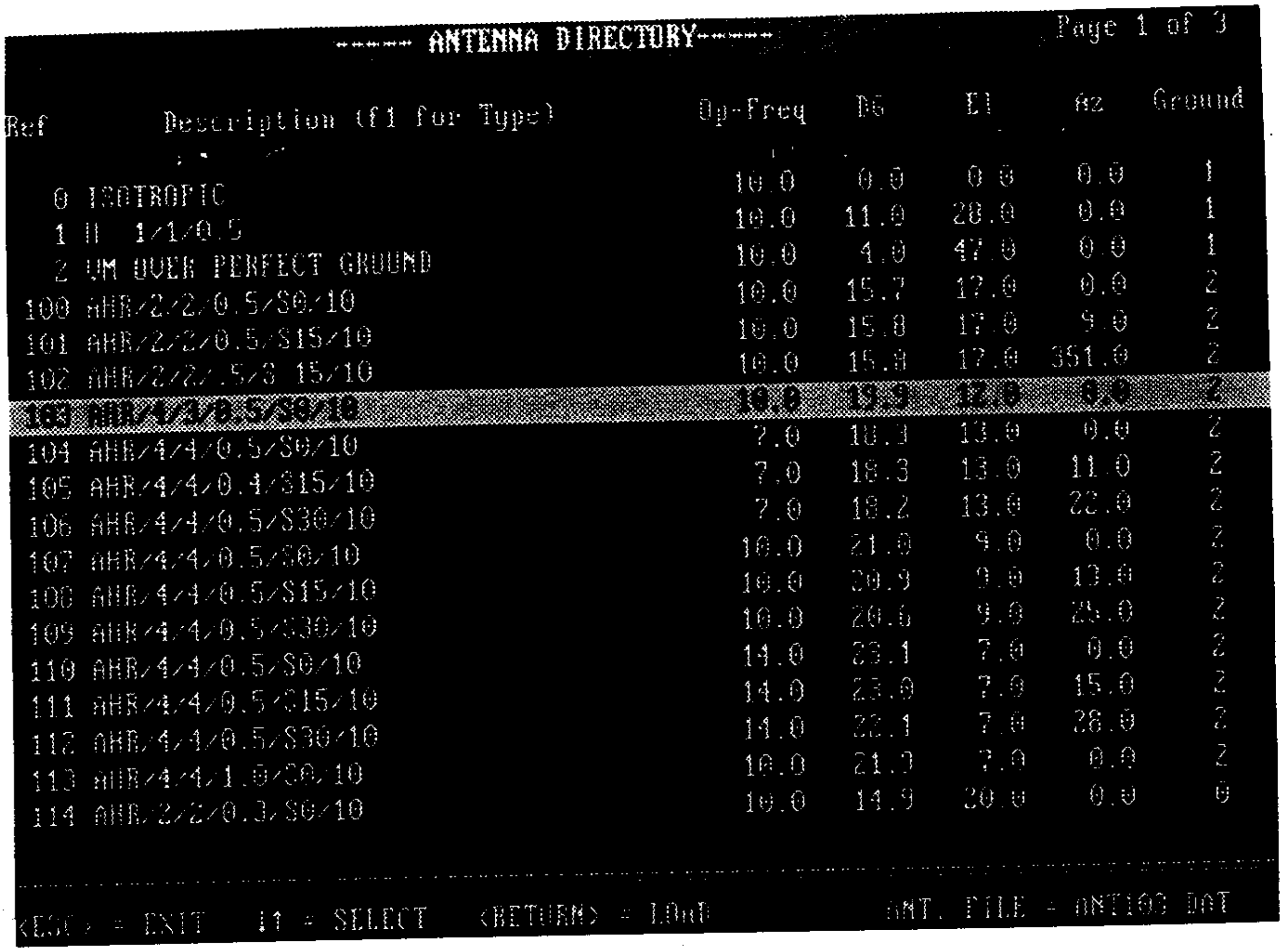


Figure 7: Example of an antenna directory display (description mode)

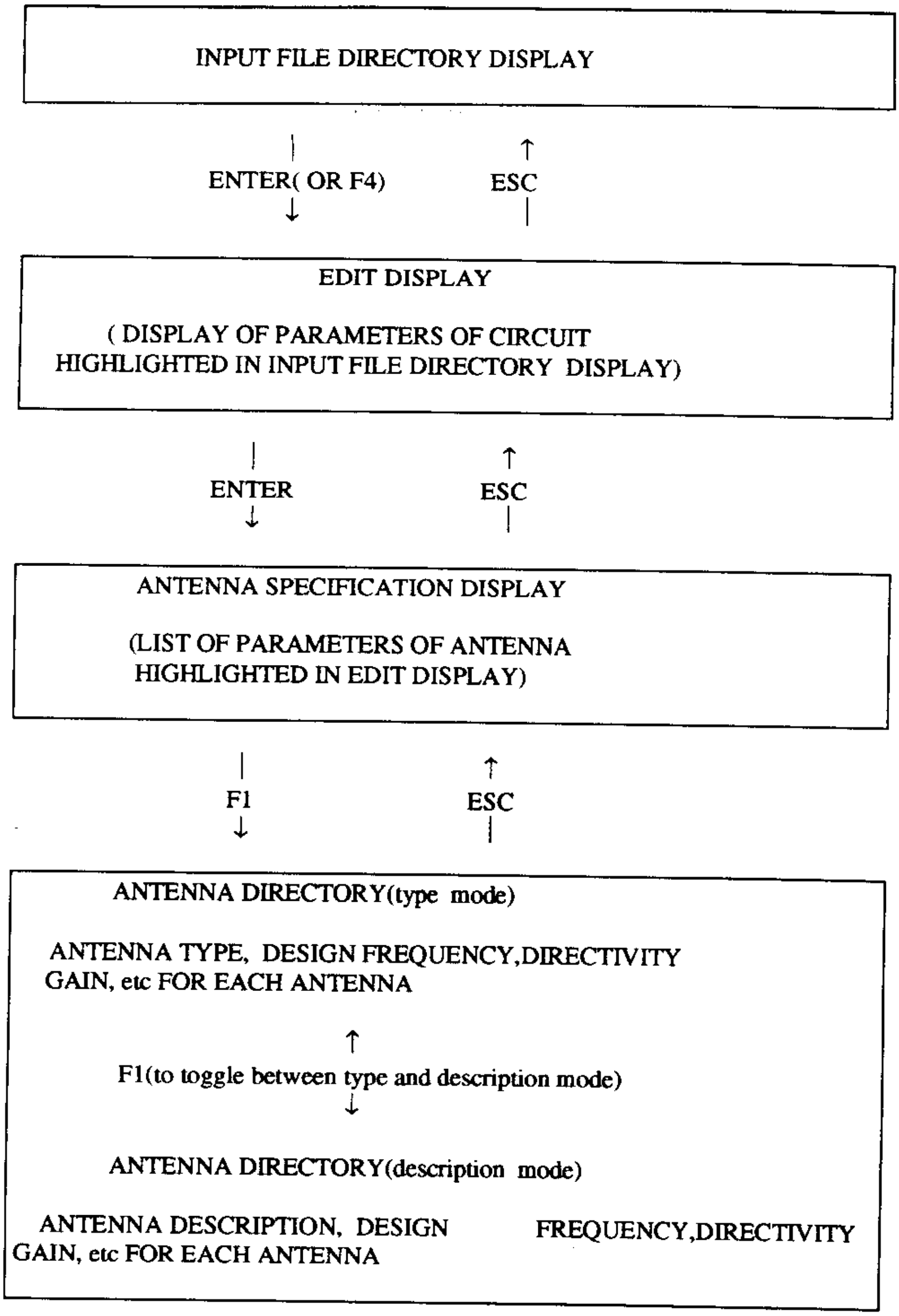


Figure 8 Hierarchy of displays (single circuit run/antenna directory access)

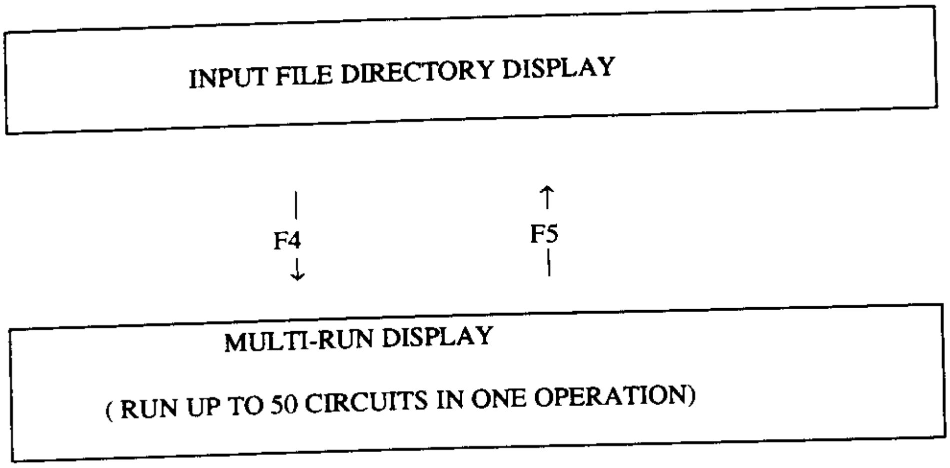


Figure 9 Hierarchy of displays (multi-circuit run option)

METHOD 1 REC533A VERS-2.0 21.JULY.93 PAGE 1

JUN 1990 SSN = 10.

SLOUGH ISOTROPE		DOURBES		AZIMUTHS	SP	N. MI.	KM
51.50 N	0.57 W	50.10 N	4.60 E	111.17	295.18	213.4	395.2

MIN ANG 3.0 DEG TBEAR 0.0 RBEAR 0.0 PWR 1.00 KW

TX ISOTROPIC 2.0- 30.0 MHz RX ISOTROPIC 2.0- 30.0 MHz

S/N% 50 NOISE CATEGORY 1 3000 HZ RX BDWTH REQ S/N 3 DB

MEDIAN FIELD STRENGTH FOR STRONGEST MODE IN DB ABOVE 1 UV/M

UT	MUF	DBU	2.0	3.0	5.0	7.0	9.5	12.0	15.0	18.0	21.5	26.0	LUF	FOT	OPMUF
1	4.6	34	35	35	24	9	-2	-10	-19	-26	-27	-28	2.0	4.7	5.6
2	4.3	33	35	35	20	7	-5	-13	-22	-27	-28	-28	2.0	4.0	4.8
3	4.3	35	37	35	21	8	-3	-11	-20	-24	-24	-24	2.0	4.0	4.7
4	4.5	35	37	37	24	10	0	-9	-17	-24	-24	-24	2.0	4.3	5.0
5	5.0	34	30	34	32	12	2	-6	-14	-21	-24	-24	2.0	4.7	5.5
6	5.4	34	23	29	34	15	4	-3	-11	-18	-24	-24	2.0	5.1	6.0
7	5.9	32	14	20	31	21	6	-2	-9	-15	-22	-24	2.1	5.5	6.5
8	6.2	31	6	14	28	25	7	0	-7	-13	-20	-24	3.0	5.8	6.8
9	6.3	30	-1	9	26	25	7	0	-7	-13	-19	-25	3.6	5.9	7.0
10	6.3	27	-6	5	24	25	7	-1	-8	-14	-20	-25	3.9	6.0	6.9
11	6.4	24	-10	2	23	24	6	-2	-9	-15	-21	-25	3.9	6.1	6.8
12	6.5	24	-11	2	23	24	6	-3	-9	-15	-22	-25	3.9	6.1	6.7
13	6.4	24	-9	3	23	24	5	-3	-10	-16	-23	-26	3.9	6.1	6.6
14	6.3	24	-5	6	24	25	4	-4	-11	-17	-23	-26	3.8	5.9	6.5
15	6.0	26	1	10	26	25	3	-4	-11	-17	-23	-25	3.5	5.7	6.4
16	5.8	28	6	13	26	21	2	-5	-13	-19	-25	-28	3.1	5.4	6.4
17	6.0	30	14	19	29	18	4	-4	-11	-17	-24	-27	2.2	5.6	6.6
18	6.4	31	22	28	32	20	8	0	-8	-14	-21	-27	2.0	6.0	7.0
19	6.9	33	29	32	32	29	12	4	-4	-10	-17	-24	2.0	6.4	7.6
20	7.1	33	35	37	34	33	13	4	-4	-11	-18	-25	2.0	6.6	7.8
21	6.8	33	36	35	34	27	11	3	-6	-12	-19	-27	2.0	6.4	7.5
22	6.2	33	35	35	34	21	8	-1	-9	-16	-23	-28	2.0	5.8	6.8
23	5.5	33	34	34	33	15	4	-5	-13	-20	-27	-28	2.0	5.7	6.7
24	5.1	32	34	34	32	11	0	-8	-17	-24	-28	-29	2.0	5.2	6.1

Figure 10: Example of Method 1 output

```
METHOD  2    REC533A VERS-2.0    21.JULY.93                    PAGE  2

             JUN      1992              SSN = 137.
TUCUMAN LPV               BUENOS AIRES           AZIMUTHS     SP     N. MI.      KM
26.80 S    65.30 W    36.70 S    58.50 W    151.45   327.85      687.9     1273.9
MIN ANG   3.0 DEG        TBEAR 151.5             RBEAR    0.0        PWR  10.00 KW
TX LPV 18/45/3/17/6/3  4.0- 30.0 MHz  RX ISOTROPIC                   2.0- 30.0 MHz
   S/N% 50       NOISE CATEGORY 2            6000 HZ RX BDWTH        REQ S/N   8 DB
```

MEDIAN SIGNAL-TO-NOISE RATIO FOR STRONGEST MODE IN DB

UT	MUF	DB	5.0	6.0	8.0	10.0	12.0	14.0	18.0	22.0	26.0	0.0	LUF	FOT	OPMUF
1	16.5	42	34	35	37	40	40	42	30	20	12	0	4.0	17.6	20.7
2	15.3	41	34	36	37	40	40	41	26	16	9	0	4.0	16.3	19.1
3	13.9	40	35	36	38	40	40	37	21	12	5	0	4.0	14.7	17.3
4	12.7	39	35	36	38	40	39	29	17	9	2	0	4.0	13.5	15.9
5	11.9	38	35	36	38	39	35	25	14	6	-1	0	4.0	12.7	14.9
6	11.2	39	35	37	38	39	29	22	12	4	-3	0	4.0	11.9	14.1
7	10.3	38	35	37	38	39	23	18	8	1	-6	0	4.0	10.9	12.8
8	8.5	37	35	37	37	23	15	10	1	-7	-14	0	4.0	9.0	10.6
9	6.7	36	35	36	21	12	5	0	-8	-16	-24	0	4.0	7.1	8.3
10	6.9	37	35	36	22	14	7	2	-7	-15	-22	0	4.0	7.3	8.6
11	10.7	39	32	36	38	39	26	19	10	3	-3	0	4.0	10.5	12.3
12	16.8	40	17	24	29	36	37	39	30	20	14	0	4.0	16.4	19.3
13	21.7	40	3	11	22	28	34	38	39	36	24	0	5.6	21.2	25.0
14	23.4	40	-9	2	16	25	28	36	38	39	28	0	6.8	22.9	26.9
15	22.8	39	-18	-1	13	22	32	36	39	39	26	0	7.1	22.3	26.2
16	21.8	39	-21	-3	11	28	32	36	39	35	24	0	7.4	21.3	25.0
17	21.2	40	-20	-2	12	29	32	36	39	32	22	0	7.3	20.7	24.4
18	21.6	40	-14	-2	14	23	32	36	39	35	23	0	6.9	21.1	24.9
19	22.7	40	-3	6	20	27	34	38	40	40	26	0	6.2	22.2	26.2
20	23.2	41	11	19	26	35	37	40	41	41	28	0	4.7	22.6	26.6
21	21.7	42	28	30	36	39	40	41	42	37	25	0	4.0	21.2	25.0
22	19.2	43	33	35	37	40	41	42	42	27	19	0	4.0	18.8	22.1
23	17.6	42	33	35	37	40	40	42	36	23	15	0	4.0	18.7	22.0
24	17.1	42	33	35	37	40	40	42	33	21	14	0	4.0	18.1	21.3

Figure 11: Example of Method 2 output

```
          JAN      1990            SSN = 170.
LONDON ANT=114         BRASILIA                 AZIMUTHS     SP    N. MI.        KM
51.00 N    0.10 W   16.00 S    48.00 W     226.61    28.41     4741.6    8780.8
MIN ANG  3.0 DEG        TBEAR 225.0             RBEAR   0.0       PWR  10.00 KW
TX AHR/2/2/0.3/S0/10    7.0- 14.0 MHz  RX ISOTROPIC               2.0- 30.0 MHz
   S/N% 50          -157 NOISE DBW          6000 HZ RX BDWTH      REQ S/N  8 DB
```

75% SIGNAL-TO-NOISE RATIO FOR STRONGEST MODE IN DB

UT	MUF	DB	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	LUF	FOT	OPMUF
1	10.5	6	-105	3	6	5	6	5	3	0	-3	-120	7.1	12.0	14.1
2	10.5	8	-102	6	8	8	8	7	5	2	-1	-119	7.0	12.1	14.2
3	11.1	11	-98	10	12	12	11	11	9	6	3	-116	7.0	12.7	14.9
4	10.3	10	-97	11	12	11	10	8	5	2	-3	-120	7.0	11.8	13.9
5	8.0	6	-98	7	6	3	-1	-5	-9	-14	-21	-142	7.0	9.2	10.9
6	7.4	6	-98	7	4	0	-4	-9	-14	-21	-29	-151	7.0	8.5	10.0
7	11.6	15	-89	19	20	19	17	16	14	10	6	-113	7.0	13.4	15.7
8	17.4	-94	-86	23	26	27	28	28	28	28	27	-90	7.0	19.1	22.4
9	20.8	-104	-213	-68	-46	-30	-19	-10	-4	1	4	-107	12.8	21.2	25.0
10	28.7	-98	-295	-147	-100	-74	-54	-40	-28	-20	-13	-122	34.5	29.3	34.5
11	34.2	-98	-329	-189	-142	-109	-78	-59	-45	-34	-25	-133	41.0	34.9	41.0
12	33.5	-98	-344	-216	-164	-117	-90	-70	-54	-42	-32	-139	40.2	34.1	40.2
13	29.9	-101	-350	-228	-174	-125	-97	-76	-59	-46	-36	-142	35.9	30.5	35.9
14	28.0	-104	-353	-230	-176	-129	-100	-78	-62	-48	-38	-144	33.6	28.6	33.6
15	28.1	-103	-354	-227	-174	-127	-99	-77	-60	-47	-37	-142	33.8	28.7	33.8
16	28.7	-101	-348	-212	-162	-117	-90	-70	-54	-41	-31	-137	34.5	29.3	34.5
17	29.1	-99	-324	-176	-133	-94	-71	-54	-40	-29	-21	-128	34.9	29.7	34.9
18	26.5	-102	-284	-136	-102	-70	-51	-37	-26	-17	-10	-119	31.8	27.1	31.8
19	21.8	-103	-218	-82	-60	-38	-26	-16	-8	-2	2	-109	13.8	22.5	26.4
20	18.2	-103	-163	-40	-22	-12	-5	1	5	8	10	-102	11.0	18.8	22.1
21	15.7	-103	-128	-12	-5	1	5	8	11	12	12	-102	9.0	16.2	19.0
22	13.8	3	-121	-8	-2	3	6	8	8	9	9	-107	8.5	15.8	18.6
23	12.4	7	-116	-4	0	3	6	6	7	7	5	-112	8.0	14.2	16.8
24	11.3	6	-110	0	3	5	5	6	5	3	0	-117	7.1	12.9	15.2

Figure 12: Further example of Method 2 output

METHOD 3 REC533A VERS-2.0 21.JULY.93 PAGE 4

JUL 1992 SSN = 119.

SWAZILAND H CURTAIN NAIROBI AZIMUTHS SP N. MI. KM

26.34 S 31.59 E 1.28 S 36.83 E 12.22 190.93 1534.9 2842.3

MIN ANG 3.0 DEG TBEAR 13.0 RBEAR 0.0 PWR 100.00 KW

TX AHR/4/4/1.0/S0/10 7.0- 14.0 MHz RX ISOTROPIC 2.0- 30.0 MHz

S/N% 50 -157 NOISE DBW 3000 HZ RX BDWTH REQ S/N 8 DB

ACHIEVED MEDIAN SIGNAL-TO-NOISE RATIO OF 8 DB INDICATED BY *

UT	MUF		3.5	5.0	6.5	8.0	9.5	11.0	13.0	16.0	20.0	0.0	LUF	FOT	OPMUF
1	8.2	*				*	*	*	*				7.0	8.7	10.2
2	6.5					*	*	*	*				7.0	6.7	7.8
3	6.7					*	*	*	*				7.0	6.8	8.0
4	12.0	*				*	*	*	*				7.0	11.7	13.8
5	21.3					*	*	*	*				7.0	19.9	23.4
6	28.5					*	*	*	*				7.0	26.6	31.3
7	29.7					*	*	*	*				7.6	27.8	32.7
8	27.5					*	*	*	*				7.9	25.7	30.3
9	25.5						*	*	*				9.0	23.9	28.1
10	24.7						*	*	*				9.1	23.1	27.2
11	24.5						*	*	*				8.8	22.9	27.0
12	25.0					*	*	*	*				7.1	23.4	27.5
13	25.9					*	*	*	*				7.0	24.2	28.5
14	26.2					*	*	*	*				7.0	24.5	28.8
15	25.4					*	*	*	*				7.0	23.8	28.0
16	23.8					*	*	*	*				7.0	22.3	26.2
17	21.5					*	*	*	*				7.0	22.0	25.9
18	18.6					*	*	*	*				7.0	19.0	22.3
19	15.8					*	*	*	*				7.0	16.1	18.9
20	13.7	*				*	*	*	*				7.0	14.6	17.1
21	12.0	*				*	*	*	*				7.0	12.8	15.1
22	10.1	*				*	*	*	*				7.0	10.7	12.6
23	8.9	*				*	*	*	*				7.0	9.4	11.1
24	8.8	*				*	*	*	*				7.0	9.3	11.0

Figure 13: Example of Method 3 output

```
METHOD  4     REC533A VERS-2.0    21.JULY.93                  PAGE   5

          JUN      1990            SSN = 148.
LONDON LOG. PER.        ROME                      AZIMUTHS     SP    N. MI.       KM
51.15 N    0.10 W   41.85 N   12.50 E   132.26  321.44      761.5    1410.2
MIN ANG  3.0 DEG      TBEAR 130.0           RBEAR    0.0          PWR  10.00 KW
TX LPH 18/35/30/30/3/  4.0- 30.0 MHz  RX ISOTROPIC                2.0- 30.0 MHz

ASSIGNED FREQUENCIES:  5.0  6.0  8.0 10.0 12.0 14.0 18.0 22.0 26.0

          PREDICTION OF BEST OPERATIONAL FREQUENCY,F
```

UT	BOF	UT	BOF	UT	BOF	UT	BOF
01	14.0	07	14.0	13	18.0	19	14.0
02	12.0	08	14.0	14	18.0	20	14.0
03	12.0	09	14.0	15	14.0	21	14.0
04	12.0	10	18.0	16	14.0	22	14.0
05	14.0	11	18.0	17	14.0	23	14.0
06	14.0	12	18.0	18	14.0	24	14.0

Figure 14: Example of Method 4 output

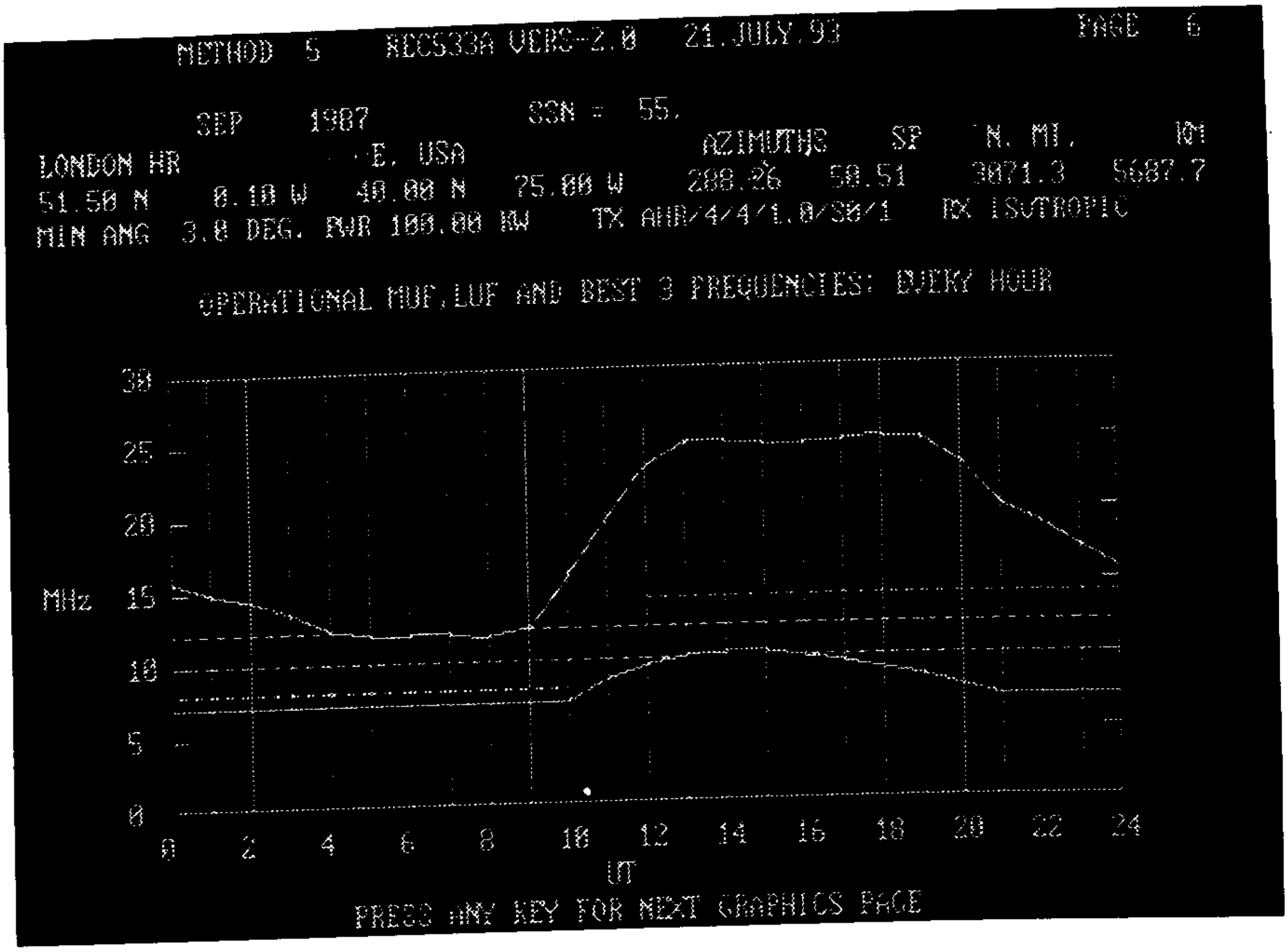


Figure 15: Example of Method 5 output

```
               METHOD  6    REC533A VERS-2.0   21.JULY.93               PAGE   7

               JUL      1977             SSN =   29.
     NORFOLK ANT=103          LUECHOW VM NO SCREEN  AZIMUTHS     SP    N. MI.        KM
     36.80 N    76.50 W   52.98 N    11.22 E       43.91   292.73    3612.6    6690.0
     MIN ANG  3.0 DEG         TBEAR  53.0             RBEAR    0.0         PWR    1.00 KW
     TX AHR/4/3/0.5/S0/10    7.0- 14.0 MHz  RX VM  8/0/0/0              2.0- 13.1 MHz
        S/N% 50          -157 NOISE DBW          3000 HZ RX BDWTH        REQ S/N  8 DB

 UT  MUF                                                                 LUF  FOT OPMUF

  2 12.0   5.0   7.2   8.1 10.9 12.5 16.4 20.0   0.0   0.0   0.0 FREQ  7.0 11.7 13.7
     3F2   3F2   4F2   3F2  3F2  3F2  3F2  3F2   0     0     0   MODE
      14     5    14     8   13   14   15   16     0     0     0 ANGL
      26  -106    19    22   26   17 -110 -117  -999  -999  -999 DBU
      32  -107    19    23   31   24 -201 -207  -999  -999  -999 S/N
     .93   .01   .81   .88  .92  .85  .01  .01   .00   .00   .00 FS/N

  6  9.9   5.0   7.2   8.1 10.9 12.5 16.4 20.0   0.0   0.0   0.0 FREQ  7.0 10.5 12.4
     3F2   6F2   4F2   4F2  3F2  3F2  3F2  3F2   0     0     0   MODE
      13    29    19    19   13   14   14   15     0     0     0 ANGL
      24  -115    15    17   14    6 -117 -123  -999  -999  -999 DBU
      29  -108    21    22   19   13 -208 -213  -999  -999  -999 S/N
     .90   .01   .82   .82  .78  .64  .01  .01   .00   .00   .00 FS/N

 10 13.7   5.0   7.2   8.1 10.9 12.5 16.4 20.0   0.0   0.0   0.0 FREQ 11.9 13.4 15.7
     3F2   3F2   6F2   5F2  4F2  3F2  3F2  3F2   0     0     0   MODE
      11    11    27    22   17   11   11   11     0     0     0 ANGL
      12  -245   -37   -22   -2   10 -114 -119  -999  -999  -999 DBU
     -80  -239   -29   -14    6   17 -206 -209  -999  -999  -999 S/N
     .01   .01   .01   .01  .39  .74  .01  .01   .00   .00   .00 FS/N

 14 16.6   5.0   7.2   8.1 10.9 12.5 16.4 20.0   0.0   0.0   0.0 FREQ 12.7 15.6 18.3
     2F2   2F2   5F2   5F2  4F2  3F2  2F2  2F2   0     0     0   MODE
       6     6    26    26   20   14    6    6     0     0     0 ANGL
    -100  -245   -56   -45  -17    0 -100 -111  -999  -999  -999 DBU
    -191  -239   -48   -37   -9    7 -192 -201  -999  -999  -999 S/N
     .01   .01   .01   .01  .05  .45  .01  .01   .00   .00   .00 FS/N

 18 16.5   5.0   7.2   8.1 10.9 12.5 16.4 20.0   0.0   0.0   0.0 FREQ 11.9 15.4 18.2
     3F2   3F2   6F2   5F2  4F2  3F2  3F2  3F2   0     0     0   MODE
      14    14    30    25   20   14   14   14     0     0     0 ANGL
    -102  -245   -52   -33  -10    5 -102 -113  -999  -999  -999 DBU
    -194  -240   -46   -28   -5   10 -194 -203  -999  -999  -999 S/N
     .01   .01   .01   .01  .11  .58  .01  .01   .00   .00   .00 FS/N

 22 17.1   5.0   7.2   8.1 10.9 12.5 16.4 20.0   0.0   0.0   0.0 FREQ  8.3 16.0 18.8
     3F2   8F2   5F2   5F2  3F2  3F2  3F2  3F2   0     0     0   MODE
      11    30    19    20   10   11   11   12     0     0     0 ANGL
     -91  -145     1     5   21   23  -90 -103  -999  -999  -999 DBU
    -182  -144     2     7   24   28 -182 -194  -999  -999  -999 S/N
     .01   .01   .26   .42  .89  .94  .01  .01   .00   .00   .00 FS/N
```

Figure 16: Example of Method 6 output

```
                                                                    PAGE    8
      METHOD  6    REC533A VERS-2.0    21.JULY.93

              OCT     1990           SSN = 140.
SYDNEY LPH              LONDON LPV              AZIMUTHS    LP     N. MI.       KM
33.83 S  151.17 E    51.00 N    0.10 W    138.20  241.62    12428.8  23016.4
MIN ANG  3.0 DEG         TBEAR 140.0              RBEAR    0.0         PWR 100.00 KW
TX LPH 18/35/30/30/3/  4.0- 30.0 MHz  RX LPV 18/45/3/17/6/3  4.0- 30.0 MHz
   S/N% 50           -135 NOISE DBW            1 HZ RX BDWTH         REQ S/N 47 DB
                                                                    LUF   FOT OPMUF
UT  MUF

 2 16.6    5.0   7.0 10.0 14.0 18.0 22.0 26.0   0.0   0.0   0.0 FREQ 19.9 16.9 19.9
      -     -     -    -    -    -    -    -     -     -     - MODE
      -     -     -    -    -    -    -    -     -     -     - ANGL
     17  -157   -67  -14   11   17   17   10  -999  -999  -999 DBU
     33  -146   -55    0   25   36   38   34     0     0     0 S/N
    .08   .01   .01  .01  .01  .13  .22  .14   .00   .00   .00 FS/N

 4 15.2    5.0   7.0 10.0 14.0 18.0 22.0 26.0   0.0   0.0   0.0 FREQ 18.3 15.5 18.3
      -     -     -    -    -    -    -    -     -     -     - MODE
      -     -     -    -    -    -    -    -     -     -     - ANGL
     21  -101   -34    3   18   20   15    6  -999  -999  -999 DBU
     37   -90   -22   17   33   38   37   30     0     0     0 S/N
    .15   .01   .01  .01  .07  .22  .20  .05   .00   .00   .00 FS/N

 6 13.1    5.0   7.0 10.0 14.0 18.0 22.0 26.0   0.0   0.0   0.0 FREQ 15.7 13.4 15.7
      -     -     -    -    -    -    -    -     -     -     - MODE
      -     -     -    -    -    -    -    -     -     -     - ANGL
     26   -36     2   21   25   19    9   -6  -999  -999  -999 DBU
     40   -25    14   35   39   38   31   18     0     0     0 S/N
    .22   .01   .01  .10  .19  .22  .10  .01   .00   .00   .00 FS/N

 8 26.8    5.0   7.0 10.0 14.0 18.0 22.0 26.0   0.0   0.0   0.0 FREQ  7.3 29.6 34.8
      -     -     -    -    -    -    -    -     -     -     - MODE
      -     -     -    -    -    -    -    -     -     -     - ANGL
     34    12    33   42   45   44   41   36  -999  -999  -999 DBU
    -17    23    45   57   59   63   63   60     0     0     0 S/N
    .01   .01   .38  .80  .85  .88  .86  .81   .00   .00   .00 FS/N

10 24.5    5.0   7.0 10.0 14.0 18.0 22.0 26.0   0.0   0.0   0.0 FREQ 19.6 25.0 29.4
      -     -     -    -    -    -    -    -     -     -     - MODE
      -     -     -    -    -    -    -    -     -     -     - ANGL
     27  -141   -56   -6   18   27   29   27  -999  -999  -999 DBU
     50  -130   -44    8   33   46   51   51     0     0     0 S/N
    .61   .01   .01  .01  .06  .42  .64  .63   .00   .00   .00 FS/N

12 22.1    5.0   7.0 10.0 14.0 18.0 22.0 26.0   0.0   0.0   0.0 FREQ 26.6 22.6 26.6
      -     -     -    -    -    -    -    -     -     -     - MODE
      -     -     -    -    -    -    -    -     -     -     - ANGL
     16  -314  -157  -61  -12    8   16   17  -999  -999  -999 DBU
     38  -303  -145  -47    2   26   38   41     0     0     0 S/N
    .18   .01   .01  .01  .01  .02  .18  .28   .00   .00   .00 FS/N
```

Figure 17: Further example of Method 6 output

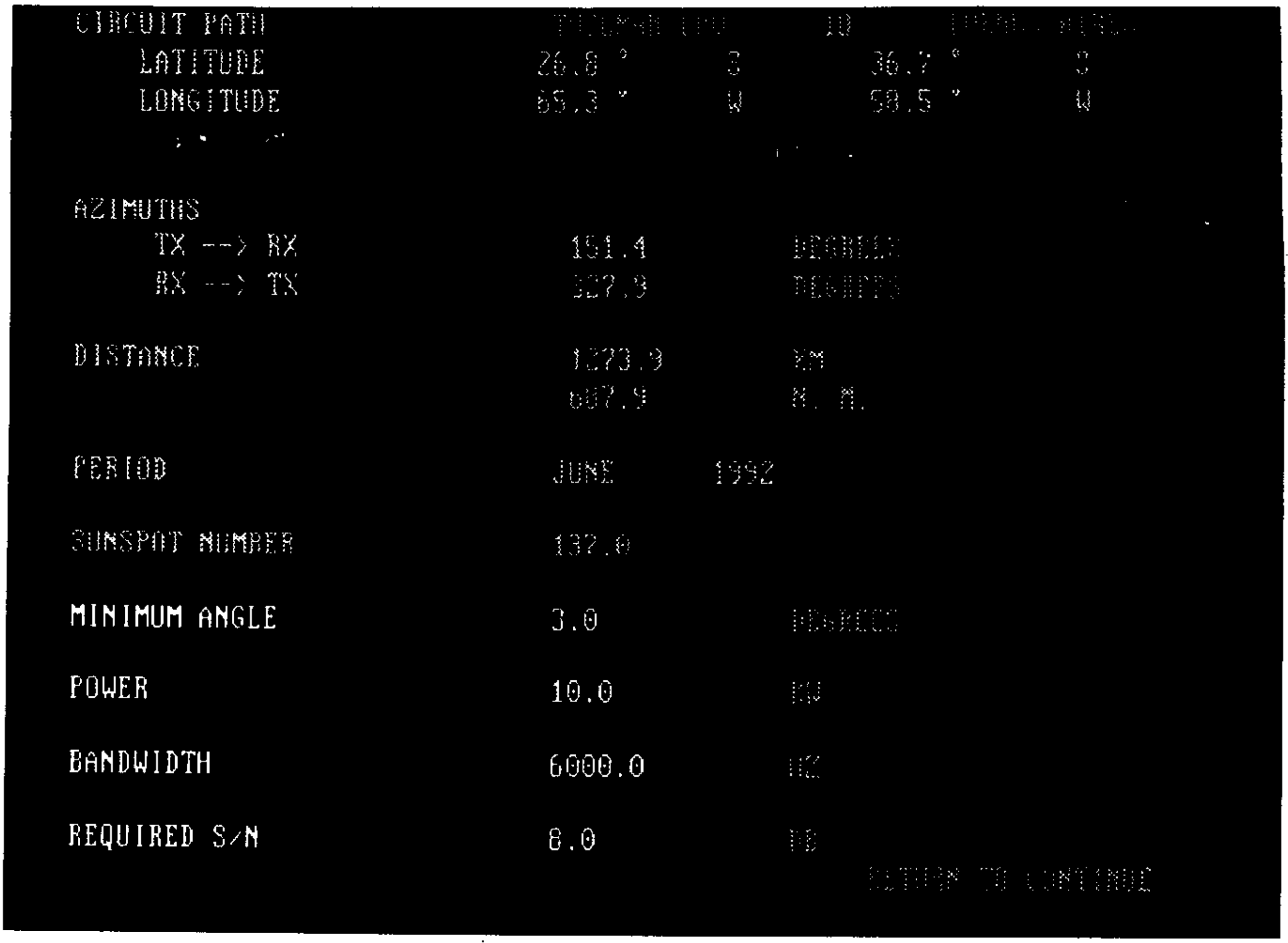


Figure 18: Example of the stand-alone graphics presentation of circuit characteristics

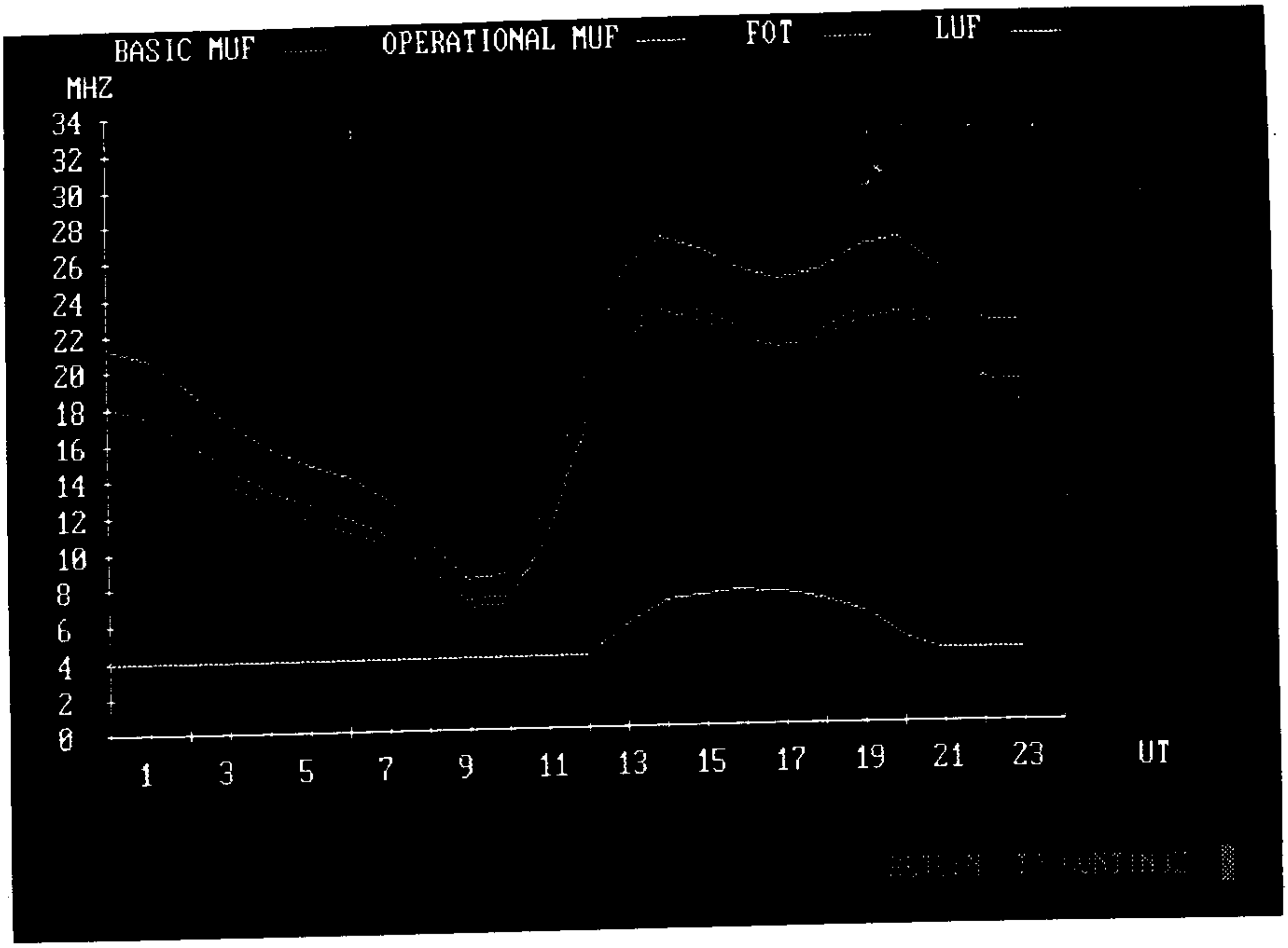


Figure 19: Example of the stand-alone graphics presentation of basic and operational MUF, FOT and LUF

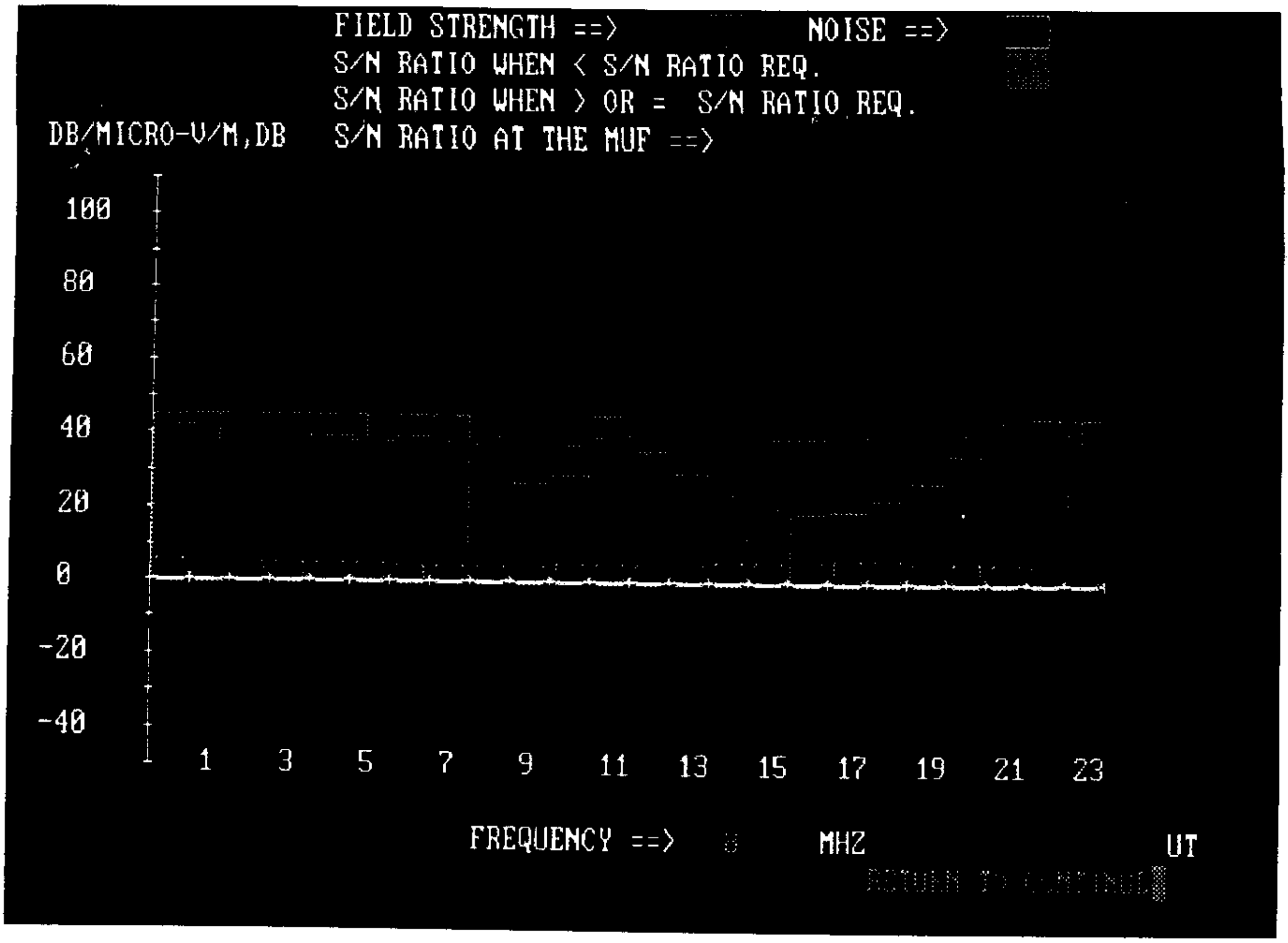


Figure 20: Example of the stand-alone graphics presentation of field strength, noise power and signal/noise for a selected frequency

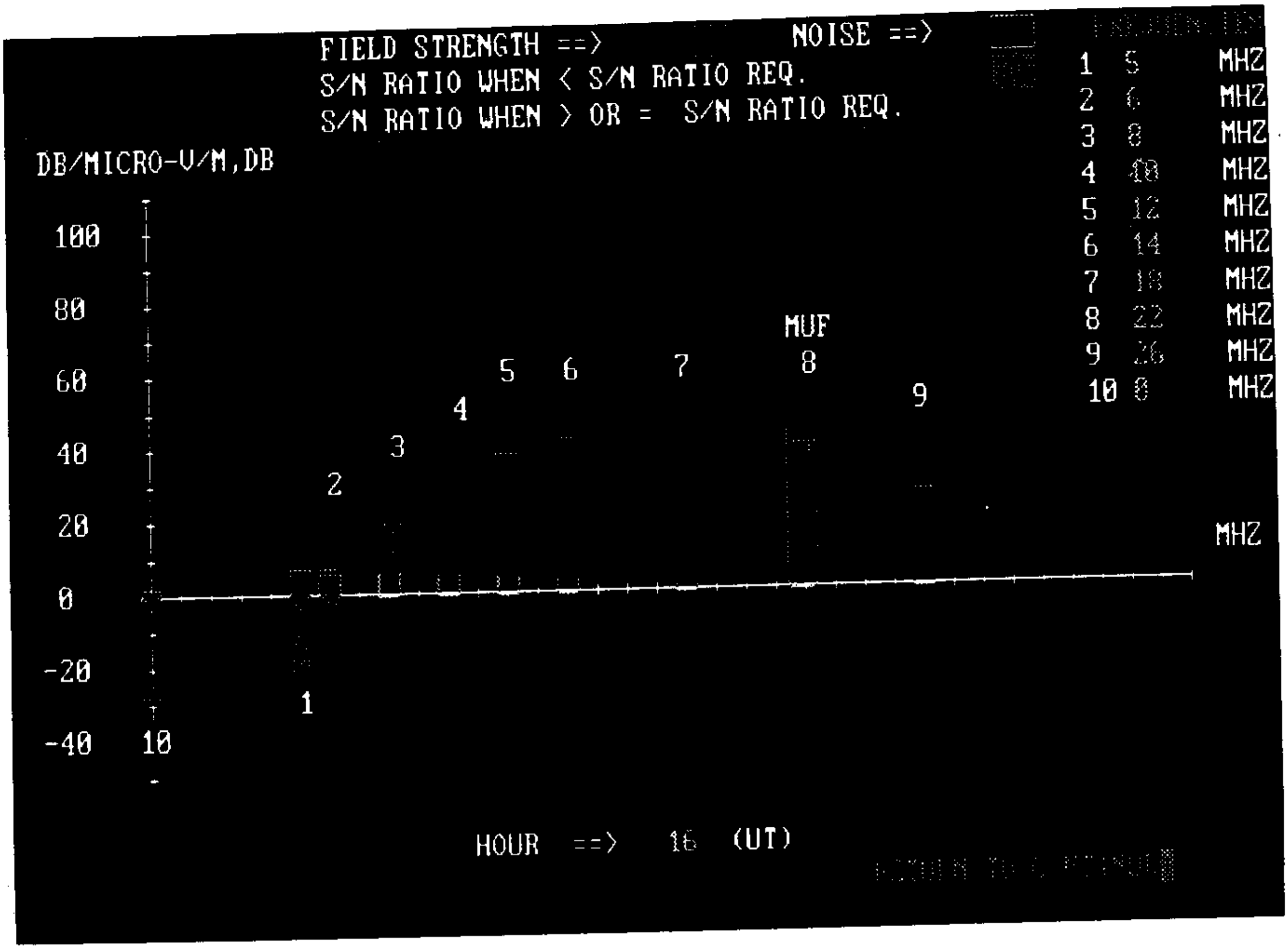


Figure 21: Example of the stand-alone graphics presentation of field strength, noise power and signal/noise for a series of frequencies at a specified UT

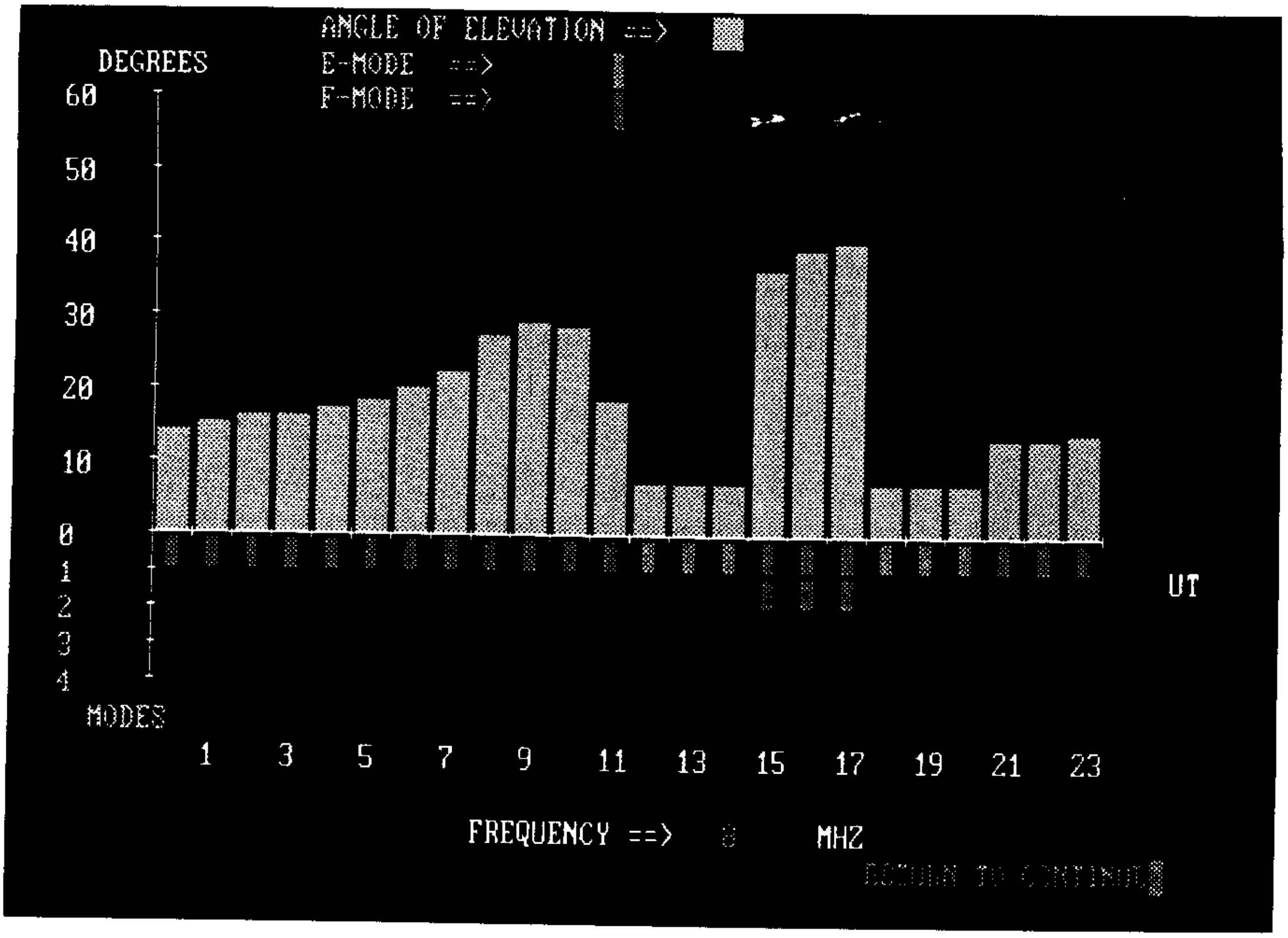


Figure 22: Example of the stand-alone graphics presentation of modes and angles of elevation for a selected frequency

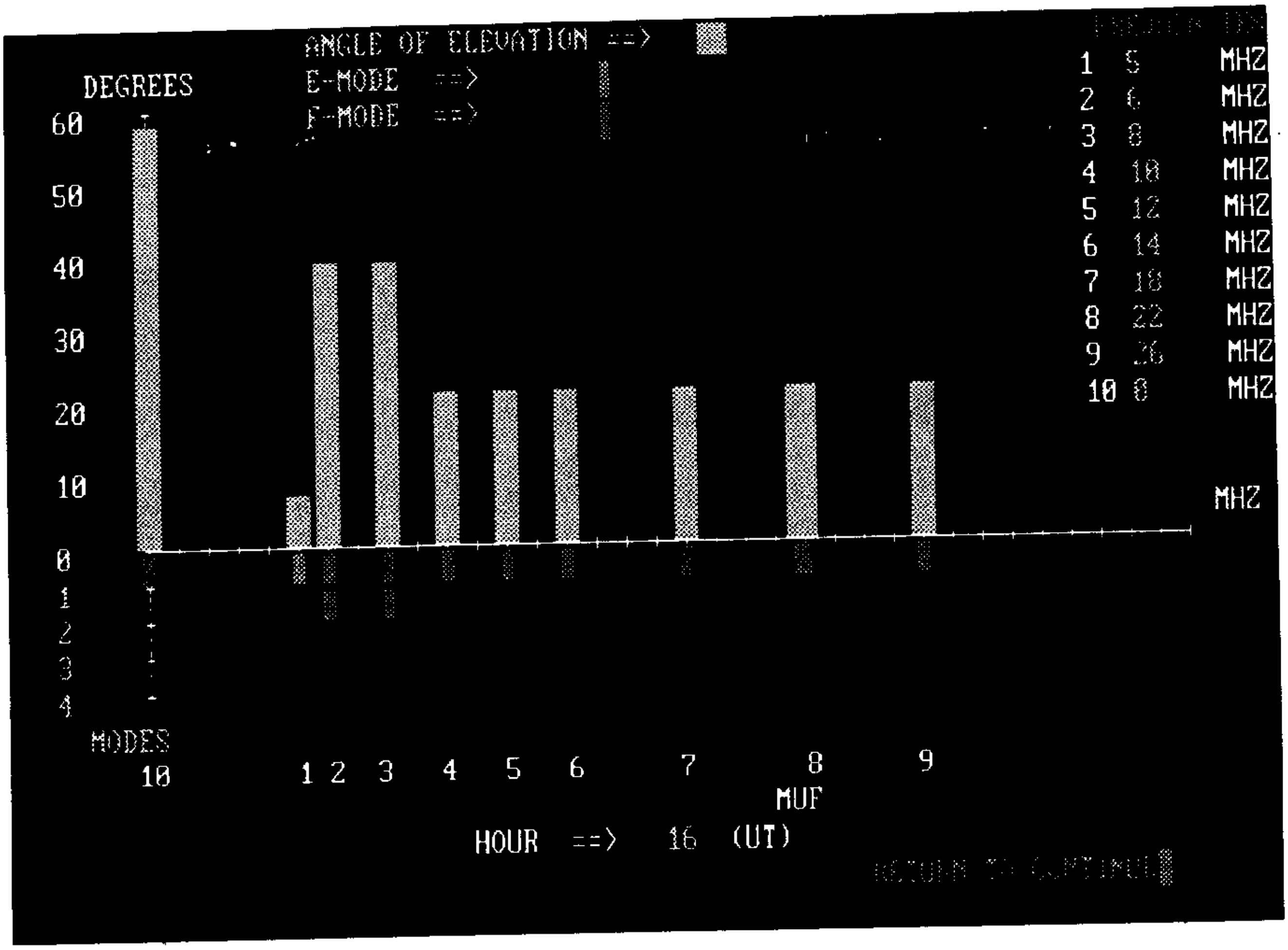


Figure 23: Example of the stand-alone graphics presentation of modes and angles of elevation for a series of frequencies at a specified UT