ROYAL SIGNALS AND RADAR ESTABLISHMENT

Memorandum 4097

TITLE: DETERMINATION OF SATCOM ACCESS POWER LEVELS WITHIN THE GROUND SEGMENT

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SUMMARY

The engineering of a large Satellite Communications Ground Station (SGT) which provides multi-carrier operation is a complex activity involving the control and management of various resources including access frequency, access power and circuit connectivity.

DETERMINATION OF SATCOM ACCESS POWER LEVELS

WITHIN THE GROUND SEGMENT

CONTENTS

1. INTRODUCTION

The engineering of a large Satellite Communications Ground Station (SGT) which provides multi-carrier operation is a complex activity involving the control and management of various resources including access frequency, access power and circuit connectivity.

This document addresses the aspect of access power and describes software developed at RSRE to determine the specific transmit powers which must be set up and maintained within a large SGT such as the UK/PSC 646 complex at RAF Oakhanger.

Such a software tool is essential considering the ever increasing volume of traffic passing through the SGT, and hence the number of accesses being radiated.

To ease the burden of the station operations personnel with the difficulties of solving the complex calculations involved RSRE Defford were requested by the SGT Engineering Authority (RAF Support Command Signals Staff) to investigate the development of suitable software.

The operational information to start the process is derived from an "Access Plan" which details how a given satellite channel is to be managed in terms of access powers and frequencies. Only the access powers are of interest here and their realisation in terms of adjustment of appropriate Attenuator Control Units (ACUs) to accord with the Access Plan.

For any currently radiated Access Plan a corresponding set of ACU settings will have been computed. Any modification to this Access Plan, either by activation or de-activation of one or more accesses, will involve re-computation to ascertain a new set of ACU settings appropriate to the new access plan.

It can be assumed that any modification to a current set of activations will involve changing the settings of all active ACUs. Similarly the total transmitted power would be expected to change; to fulfil this requirement the individual access powers are summed. In addition the subsystem power levels are calculated for use during anomally or fault investigation.

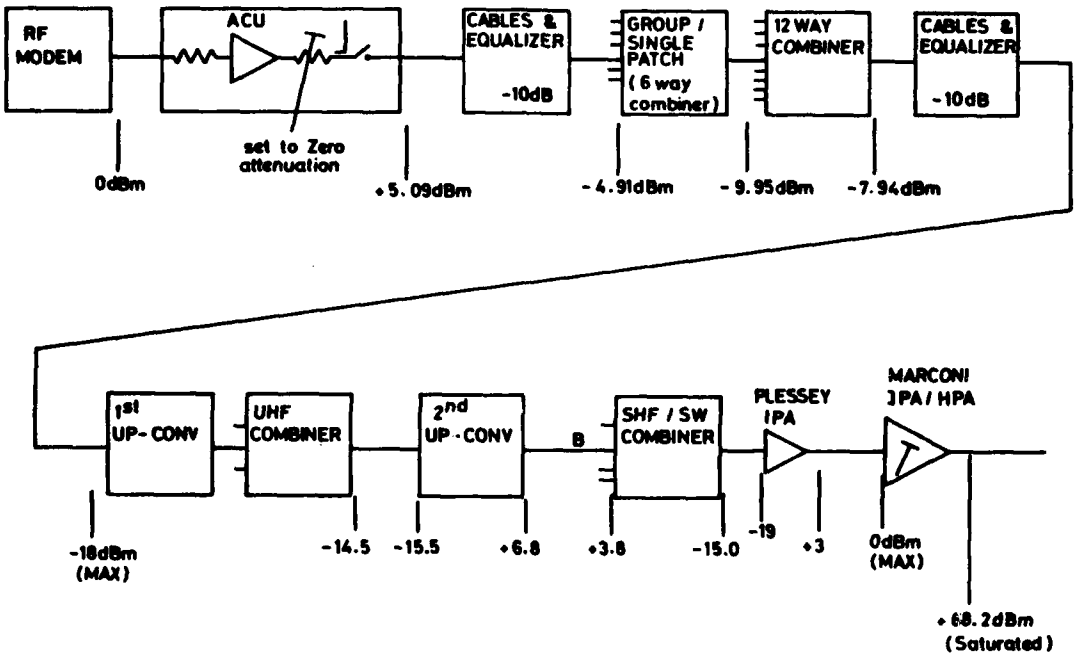


FIG.1 IF / RF SUBSYSTEM MAXIMUM POWER LEVELS

The software is written in BASIC 4.0 for use on HP 9826 or HP 9836 desk top computers. Due to the considerable computer memory required to run the ACU-SET program only a reduced number of the BASIC 4 Language Extensions files can be accommodated when using the HP 9826s fitted with 655 kbytes of RAM. The modified Language Extensions disc has all files not required deleted; the disc is now labelled "Special Extensions" to differentiate it from the HP supplied Language Extensions.

The software is organized to allow the RAF staff to maintain a log of the current state of access activation, and the ability to add, delete or amend accesses as requirements change.

2. PRINCIPLES

For a given gain of the IF/RF subsystems within the SGT the transmit power of any access is directly proportional to the drive level from its associated RF modem. Each modem has a dedicated Attenuator Control Unit (ACU) which allows the effective modem drive level to be adjusted in 1 dB steps over a 50 dB range from nominally 0 dBm to -50 dBm. The logarithmic relationship between access powers (detailed in an Access Plan in units of watts) can thus be translated into settings of the appropriate ACUs.

Limitations in the design of the IF/RF subsystem dictate restrictions in drive levels to certain subsystem elements. For instance, the 1st upconverter input must not exceed -18 dBm, and for the IPA (within the HPA) the drive level must not exceed 0 dBm.

These power levels can be achieved by a single RF modem with its associated ACU set for minimum attenuation. An identical drive level from a second RF modem will cause the input level of the driven 1st upconverter to exceed the -18 dBm threshold by 3 dB hence both modem drives require backing-off by 3 dB. In a similar way backing-off will be required if the combined power from a number of 2nd upconverters causes an excessive power level at the IPA input.

The software is designed around the above principles in order to compute the required ACU settings for each access based upon the envisaged Daily Access Plan (DAP). The total transmitter power required to support this DAP is based on summing the individual access powers in order to complete the information required by the SGT operations staff. Modification to a currently existing DAP entails re-computing of all ACU settings prior to an activation or de-activation in order to maintain (or limit) the input power to the 1st upconverter and IPA/HPA, to maintain the relative transmit powers specified in the Access Plan, and to establish the total transmitter power required. Subsystem power levels are based upon current knowledge of the loss and gain elements within the IF/RF subsystem, as briefly shown in Figure 1, and the computed powers at each input of the various combiners.

Algorithms:

(i) To convert watts to dBm.
Let an access have a power of A watts.
Let the result in dBm be B.
Then,

$B = 10\ (\log_{10}\ (A \times 1000))$ dBm.

(ii) To convert dBm to watts.
Let an access have a power of A dBm.
Let the result in watts be B.
Then,

$B = (10^{A/10})/1000$ watt

(iii) To calculate the total power in dBm of 3 single accesses A, B and C all quoted in dBm.

Firstly, let $AA = 10^{A/10}/1000$ watts.

let $BB = 10^{B/10}/1000$ watts.

let $CC = 10^{C/10}/1000$ watts.

Then, total power in watts = AA + BB + CC.

Lastly, convert this back to dBm,

ie. Total Power $= 10(\log_{10}((AA + BB + CC) \times 1000))$ dBm.

(iv) Determination of ACU settings.

1. Find all ON accesses.
2. Find the largest ON access.
3. Set the ACU of the largest ON access to 0 dB initially.
4. Convert transmit powers of all ON accesses to dBm values.
5. Assign dB values to all ACUs that are fed with an ON access based on the results from step 4.

6. Allowing for combiner/equaliser losses, etc, calculate the powers at the first upconverter inputs derived from each active ACU output level, (see Figure 1).
7. Calculate the power (in dBm) at each first upconverter output.
8. Convert these all to watts then sum them.
9. Allowing for the UHF combiner, etc, losses and gains, determine the powers at each second upconverter input, and the total power at each second upconverter output.
10. Allowing for losses/gains of the SHF combiner and Plessey IPA, etc, determine the total power at the IPA (/HPA) input.
11. Look for the largest first upconverter input power. If this exceeds -18 dBm then back off ALL ACUs by the excess amount otherwise go to step 13..
12. Go to step 6 and re-calculate the power levels.
13. If the input power level to the IPA/HPA exceeds 0 dBm then back off ALL ACUs by the excess amount and return to step 6.
14. If the limits dictated in steps 11 and 13 are not exceeded the computation is complete.

(v) Having determined the ACU attenuator settings resulting from the above procedures, simple algorithms can be described to compute the power levels at various points in the RF subsystem. These algorithms are based on the known losses and gains of the subsystem elements and interconnections as outlined in Figure 1.

Power at 6 way combiner i/p = 5.09 - (calculated ACU setting) - 10 dBm.

Power at 6 way combiner o/p = sum of input powers - combiner loss dBm.

Power at 12 way combiner i/p = power at o/p of 6 way combiner - any cable loss dBm.

Power at 12 way combiner o/p = sum of input powers - combiner loss dBm.

Power at 1st u/c i/p = power at 12 way combiner o/p - 10 dBm.

Power at UHF combiner o/p = sum of input powers to 1st u/c's + 3.5 dBm.

Power at 2nd u/c i/p = power at UHF combiner o/p + 1 dBm.

Power at 2nd u/c o/p = power at 2nd u/c i/p + 22.3 dBm.

Power at SHF/SW combiner i/p = power at o/p of 2nd u/c - 3 dBm.

Power at SHF/SW combiner o/p = sum of input powers to SHF/SW combiner - 18.8 dBm.

Power at Plessey IPA i/p = SHF/SW combiner o/p power - 4 dBm.

Power at Plessey IPA o/p = Power at Plessey IPA i/p + 22 dBm.

Power at IPA/HPA i/p = Plessey IPA o/p power - 3 dBm.

Power at IPA/HPA o/p = IPA/HPA i/p power + 68.2 dBm.

3. MAN-MACHINE INTERFACE

The large number of accesses likely to occur in the future indicate that storage of previous and current entries should be held in data files; currently a disc based data file is used for each first upconverter including TT&C, and also for GMF.

Graphics are used where possible to enable easy use of the facilities available together with maximum selection of options via softkeys.

Each access entry consists of:

a) a DCN serial number (or any numeric upto 6 characters in length).
b) the transmit power of the access (in watts).
c) the access state (ON is activated, with the ACU isolation switch closed; OFF is the reverse).

All accesses are grouped with the appropriate first upconverters depending on the frequencies of the accesses. The choice of connectivity is determined by the operational staff using other management tools; it does not form part of this report.

Access details are maintained in files, one file for each first upconverter. Selection of any upconverter causes one or more pages to be displayed containing all previously entered (and consequently stored) accesses. Any access can be deleted from file, activated or de-activated, or new accesses added as required. Between 1 and 40 accesses can be accommodated for each first upconverter (9 comms plus 1 TT&C); GMF access is treated differently and is discussed later.

The result of amending an access power or its state (ON/OFF) is that all the ACU settings and the total transmit power will be re-computed. The pages will then display the original (OLD) ACU settings alongside the NEW settings. During computation both the first upconverter and IPA/HPA input levels are examined to ensure that neither exceeds pre-determined limits (-18 dBm and 0 dBm respectively). The OLD and NEW ACU settings are displayed to an accuracy of 0.1 dB hence allowing the operator to ignore very small adjustments since

the attenuators have a resolution of 1 dB. The displayed results can be hard copied to a suitable printer (HP Model 2671G) for any selected first upconverter.

In the case of a GMF access the program computes the "ACU" attenuation required to reduce the nominal +3.8 dBm at the interface to the SHF combiner. This is the level which, if there were no other drives to the SHF combiner, would produce 0 dBm at the IPA/HPA input.

Graphics representing the IF/RF subsystems are available to the operator notated with computed subsystem power levels at various points from the first upconverter inputs to the HPA output. The graphic displays can be dumped to the printer if required.

4. OPERATION

4.1 Start

4.1.1 Cold Start

The computer must be loaded with two floppy disks, one labelled "BASIC 4.0" and the other "SPECIAL EXTENSIONS". The routine for performing the cold start is as follows:

i Ensure the computer is OFF.

ii Insert the "BASIC 4.0" floppy disk into the drive (if using a HP9836 computer this must be the right hand drive). Basic 4.0 will now begin to load, once the computer has been turned ON.

iii After approximately 15 seconds the message "Remove Basic 4.0 . . ." will appear. Remove the "Basic 4.0" disk and insert the "Special Extensions" disk, then press the CONTINUE key.

iv Once loaded the message "Ready" will appear.

v Remove the "Special Extensions" disk.

vi Insert the "Freq'X4, ACU-SET, NULL "disk into the disk drive: Type LOAD "ACU-SET" then press the EXECUTE key. The program now loads.

vii Press the RUN key to start the program.

4.1.2 Warm Start

The computer is already ON, and the operating system on 2 floppy disks will already have been loaded. To run the ACU SETTER program take these steps:

i Insert the "FREQ-X4, ACU-SET, NULL" disk into the drive.

ii Type LOAD "ACU-SET" then press the EXECUTE key. The program will now load.

iii Press the RUN key to start the program.

4.2 Initialisation

4.2.1 Timeset

If the time and date have not been set up, the computer will ask for the new time and date to be entered. The display will be:

> Please enter the new date
> eg. 09 JUL 1986, then press ENTER
>
> Please enter the new time
> in zulu hours eg. 14.12.35, then press ENTER.
> NOTE: Times like 8.05 a.m. G.M.T.
> must be entered as follows: 08.05.00.

If information is not put in correctly, the user will be asked to input it again.

4.2.2 Loading data from disk.

The computer display will be:

> Program to calculate ACU SETTINGS
> and SYSTEM POWER LEVELS
> **********
> Please ensure data files disc is
> inserted. Now press CONTINUE

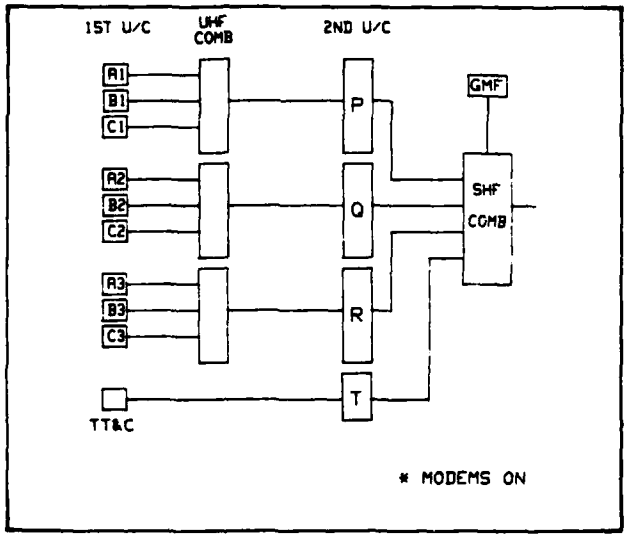
The display now reads:

> Now loading access data from disc.....

The above display should be present for approximately 15 seconds while all information about each of the first up-converters is loaded off disk.

4.2.3 Display 1 appears once data has been loaded.

This display will be:



Choose required 2nd U/C, TT&C or GMF

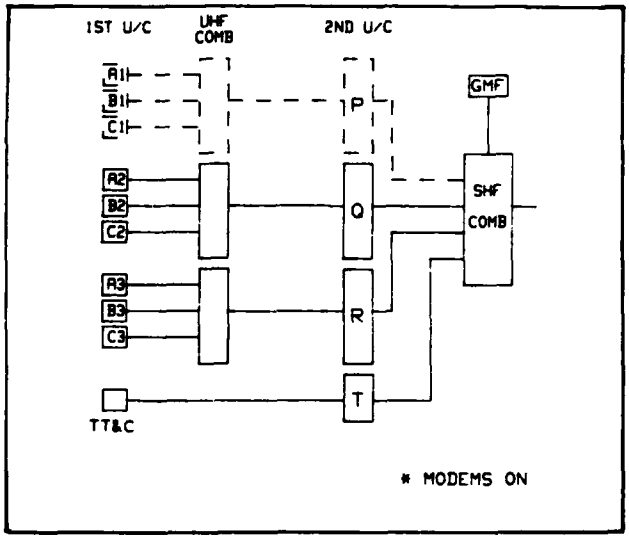
P	Q	R	T	GMF

The display shows the FSC 646 up-converter system for a single RF head. Each asterisk indicates that one or more RF modems are connected through to a first up-converter ie. the ACU isolation switch(es) is closed. TT&C has its own separate first and second up-converters. The GMF equipment has built in up-converters, and interfaces directly with the SHF combiner at a nominal power level of +3.8 dBm. This level produces 0 dBm at the IPA/HPA input.

There are 2 rows of 5 softkeys each at the bottom of the computer display. Select relevant softkey to indicate which second up-converter, TT&C or GMF is to be used.

(If the user chooses either TT&C or GMF then go straight to section 4.3)

The display will be as shown below if 'P' has been selected:



Choose 1st U/C for use with 2nd U/C 'P'

A1	B1	C1		

The display is similar to the previous one except that the 'P' converters are highlighted. Select the appropriate softkey for the required first up-converter.

4.3 Main Display and Menu Options

After approximately 5 seconds, the display will be as shown below if first up-converter 'A1' had been selected.

*** 1st U/C 'A1' ***

D.C.N. NUMBER	ACCESS POWER(W)	A.C.U. OLD	SETTING NEW
300101	30	12.6	12.6
300102	30	12.6	12.6
300103	11	OFF	OFF
300104	17	OFF	OFF
300105	65	OFF	OFF
300106	68	OFF	OFF
300107	81	OFF	OFF
300108	26	OFF	OFF
300109	63	OFF	OFF
300110	62	OFF	OFF

Page UP	Changes	Amend		Exit
Page DOWN		Printer	Syst Pwrs	CONTINUE

The accesses resulting from connecting a number of RF modems to each first up-converter are displayed as "Pages". DCN numbers are in numerical order. The second, third and fourth columns indicate transmit power for each DCN number, existing ACU setting, and computed ACU setting respectively. OFF indicates a DCN access which is not transmitting at present. The options shall now be described:

a) Page UP

Each page displays a maximum of 10 accesses. To view more than 10 accesses (ie. other pages), the user must select this softkey.

b) Page DOWN

Similar to page UP, except that it allows the user to view previous pages of accesses.

c) Changes

This allows the user to verify whether any alterations (eg. additions, deletions, etc) have been made to any of the DCN accesses.

Note: Only up to the last 10 accesses altered will be displayed.

An example display would be:

The latest changes have occurred:
****

Accesses amended are: 300101, 300101,

Accesses added are:

Accesses deleted are:

Pages				

The above example shows that DCN access 300101 has been altered twice.

The softkey "Pages" allows the user access back to the main display.

d) Amend

This gives rise to a number of options and the display would be:

OPTIONS.....

Add.....ADD ACCESS TO LIST.
Amend...AMEND AN ACCESS.
Delete..DELETE AN ACCESS.

Press relevant SOFT KEY.

Add	Amend	Delete		
				Pages

"Pages" allows the user access back to the main display.

The softkey options available are:

i. Add - This allows the user to add an access to the currently selected lst upconverter.

The display would be:

ADD AN ACCESS TO A LIST

Input D.C.N. Number then press ENTER

The number entered must not exceed 6 numeric digits in length otherwise the user will be asked to input it again.

Note: No letters may be used. If a letter is used the computer will generate an error. The cursor would then be positioned directly under the offending character. Re-enter the correct digit, then press the ENTER key.

Once entered correctly the display will be:

Enter access power in WATTS, then press ENTER.

The user must enter a value of transmit power which lies between the limits 0.001 and 10,000 watts. A value outside this range will cause the computer to request a new value.

The display will then become:

What is the new state. Press relevant SOFT KEY

ON				OFF

"ON" represents closing the ACU isolation switch in order to transmit the access.

Having selected either of these softkeys the correct operator entries can now be confirmed:

NEW ACCESS RECORD IS:

D.C.N. Number : 300128
Access Power (W) : 15
Current State : ON

Is this correct...?

Yes				No

If "No" is selected the user will be asked to re-enter the data.

If "Yes" is selected, the display will be:

Do you wish to save the data at this time...?

Yes				No

Note: If performing a number of changes to a particular first up-converter be sure to save the data at regular intervals.

If "Yes" is chosen the new record will be saved onto the ACU_SET data files disc and the display will become:

Now saving new info to disc...
Please wait.

Whether "Yes" or "No" had been selected, the display will now be:

Do you want a list of the ON accesses?

Yes				No

"No" returns the user to the main display, other wise the display will become:

Do you want a listing to the
Screen or to the Printer?

Screen				Printer

If the user selected "Screen the display will be:

***** List of ON accesses *****

DCN NO.	TX POWER (W)	1st UC	2nd UC
300128	15	A1	P
300101	30	A1	P
300102	30	A1	P
300201	30	B1	P
300202	30	B1	P
300301	0.16	C1	P
300401	30	A2	Q
300402	30	A2	Q
300701	30	A3	R
300702	30	A3	R

Use SHIFT key with KNOB to SCROLL.

				Continue

If "Printer" had been selected, the hardcopy would have been similar except that a timetag would have been added.

Pressing "Continue" allows the user to return to the main display.

ii. Amend

The display will be:

D.C.N. Number	Power Reqd. (W)	State (ON/OFF)
300101	30	ON
300102	30	ON
300103	11	OFF
300104	17	OFF
300105	65	OFF
300106	68	OFF
300107	81	OFF
300108	26	OFF
300109	63	OFF
300110	62	OFF

Scroll UP		Select		Exit
Scroll DOWN				

Only 10 accesses can be viewed at any one time on the display. To select an access off the display, the user must press the "Scroll Up" softkey once for each access. If pressed only once, the display in this example would be:

D.C.N. Number	Power Reqd. (W)	State (ON/OFF)
300102	30	ON
300103	11	OFF
300104	17	OFF
300105	65	OFF
300106	68	OFF
300107	81	OFF
300108	26	OFF
300109	63	OFF
300110	62	OFF
300128	15	ON

Scroll UP		Select		Exit
Scroll DOWN				

If the user wanted to alter DCN number 300128, then by continuing to press the "Scroll Up" softkey, 300128 will line up with the arrow (< ---).

The display will then be:

D.C.N. Number	Power Reqd. (W)	State (ON/OFF)	
300128	15	ON	<---

Scroll UP		Select		Exit
Scroll DOWN				

The user must now press the "Select" softkey and the display will become:

ALTERATIONS:

Change power level.....POWER
Change current state...STATE

Press relevant SOFT KEY

POWER		STATE		

If the user selected "Power" the display will be:

You have chosen:

D.C.N NUMBER : 300128
Required Power in Watts : 15
What should it be...
Enter new value then press ENTER

If the user selected "State: the display would be:

STATE CHANGE:

Current State is ON
Select relevant SOFT KEY

ON				OFF

Having completed altering the required DCN accesses, the user would then press "Exit".

iii. Delete

The display will be:

DELETE ACCESS ROUTINE:

Which access to DELETE.
Input DCN number then press ENTER

If the user had entered a DCN number which did not exist, the computer would ask for a new DCN number to be entered. The display should then be.

DELETE RECORD CHOSEN:

D.C.N. Number.....300128
Required Power (W)..15
Current State.....ON

DELETE this record. Are you sure...?

Yes				No

e. Printer

The display will be:

Please ensure that the printer is
connected to the HP computer and
that the printer HPIB address is
set to 701.

Start				

The user selects "Start" to commence hardcopy to a printer of all the DCN accesses, their powers and ACU settings for the particular first up-converter as shown on the main display. Once finished printing the user will automatically be returned to the main display.

f. System Powers

The display will be:

Display all subsystem Parameters.
ie. for all 1st up-converters.....All

Selective display of parameters.
ie. for one up-converter only.....Select

Tabulated printout of
System Parameters.....Print

Graphical representation
of System Parameters.....Graph

All	Select	Print	Graph	

The options shall now be described:

i. All

The user is shown successive displays of subsystem power levels relating to each first up-converter and also for TT&C. A typical display would be:

SUBSYSTEM POWER LEVELS: 'A1'

First U/C input..... -26.29 dBm
UHF Combiner output..... -20.64 dBm
2ND U/C input..... -21.64 dBm
2ND U/C output..... .66 dBm
SHF sw/combiner input... -2.34 dBm
SHF sw/combiner output.. -14.999 dBm

IPA/HPA input..... .001 dBm

Tx power required..... 75W

Highest ACU setting is.. 15.7 dB

Next Page

ii. Select

The display will be:

SELECTIVE PRINTOUT:

Select requried 1st up-converter

A1	B1	C1	A2	B2
C2	A3	B3	C3	Pages

By selecting one of the softkeys the user would obtain subsystem power levels referring to that particular first up-converter. An example would be:

SUBSYSTEM POWER LEVELS: 'B1'

First U/C input..... -27.66 dBm
UHF Combiner output..... -20.64 dBm
2ND U/C input..... -21.64 dBm
2ND U/C output..... .66 dBm
SHF sw/combiner input... -2.34 dBm
SHF sw/combiner output.. -14.999 dBm

IPA/HPA input..... .001 dBm
Tx power required..... 60W
Highest ACU setting is.. 12.7 dB

Printer				Continue

Note: Selecting "Printer" will give a hardcopy to the printer of what is already on the computer display.

iii. Print

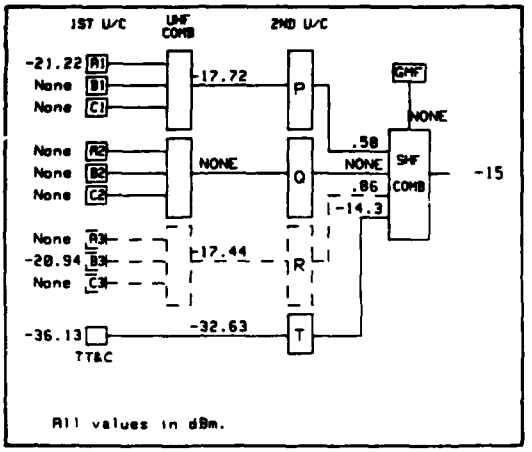
This wll give a hardcopy as below:

13 Feb 1987 14:13

1st U/C inputs	2nd U/C inputs	SHF sw/combiner inputs
A1 : -26.69 dBm	P: -21.64 dBm	P : -2.34 dBm
B1 : -27.66 dBm	Q: -25.16 dBm	Q : -5.86 dBm
C1 : -63.4 dBm	R: -25.16 dBm	R : -5.86 dBm
A2 : -27.66 dBm		TT&C: None
B2 : None		GMF : 1.13 dBm
C2 : None		
A3 : -27.66 dBm		
B3 : None		
C3 : None		
TT&C: None		

iv. Graph

Allows the user to examine power levels at various points in the system graphically. An example display would be:

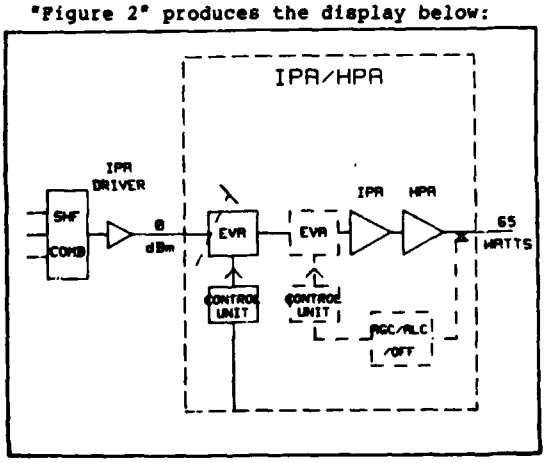


Pages		Figure 2		Printer

"Pages" returns the user to the main display.

"Printer" produces a hardcopy to printer of the graphics.

"Figure 2" produces the display below:

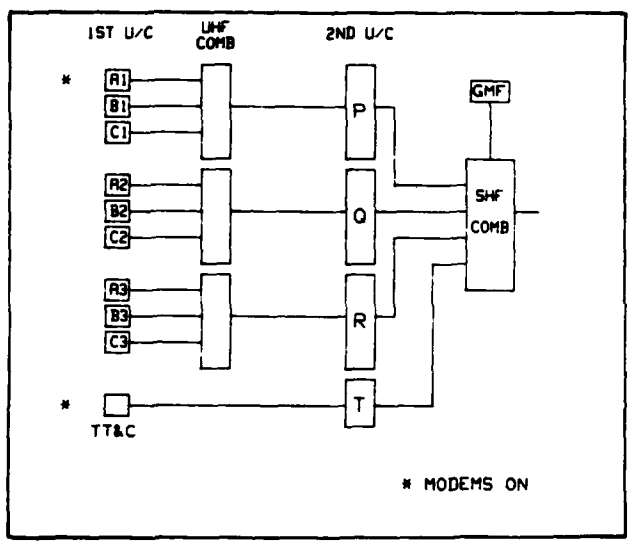


Pages		Figure 1		Printer

The user can either return to Figure 1, return to the main display or obtain a hardcopy as shown.

g. Continue

Allows the user to return to the drawing below in order to select another first up-converter, TT&C or GMF (with relevant selected second up-converter).



Choose required 2nd U/C, TT&C or GMF

P	Q	R	T	GMF

h. Exit

This ends the progrm

5. CONCLUSIONS

The software package described in this document has been assessed by the Operations personnel at RAF Oakhanger. With the minor amendments outlined in Section 5 it should form the basis of an essential computational tool for implementation on the stations Control and Monitoring processor.

6. RECOMMENDATIONS

1. Limitations in the amount of available RAM in the HP 9826S desk top computer constrained the number of RF modem/ACUs available for connection to any 1st up-converter to 40. It is recommended that the limit should be increased to a number suitable for use with the hardware available in the SGT.

2. As a result of a misconception in the method of adjusting the ACUs the current software produces settings which show a constant error of G dB. This does not abrogate the usefulness of the software providing the G dB amendment is made t` the results. Since this is merely a modification to the effective system gain it is suggested that any amendments to the software should enable the gain of each element within the subsystems to be changed easily if and when necessary. With the likelihood of wideband second upconverters (and first downconverters) being introduced into the FSC 646 together with the associated combiner (and splitter) modifications, some software changes to the loss/gain element values in the IF/RF subsystems will be required in any case.

3. It is also recommended that consideration be given to providing the Enhanced C&M Computer with facilities for automatically adjusting all the ACUs on a single command by an operator. Since every ACU could need adjustment for each activation or de-activation lack of such a command capability would result in a particularly operator intensive duty especially when the station is controlling a large number of accesses. It must be stressed that the operator should have the final say before any or all of the ACUs are changed.

4. Plessey are currently investigating the frequency/gain characteristics of the IF/RF subsystems. It is recommended that when these results are available they be incorporated into this software.

5. Subsequent discussions with Operations Staff at RAF Oakhanger on their experiences with using the ACU-SET tool have suggested a number of minor changes (Ref 1) which would make the tool more operationally acceptable.

Reference 1: OAKR/1050/28/Air dated 14 June 1987 to RAFSCSS Comms 1.

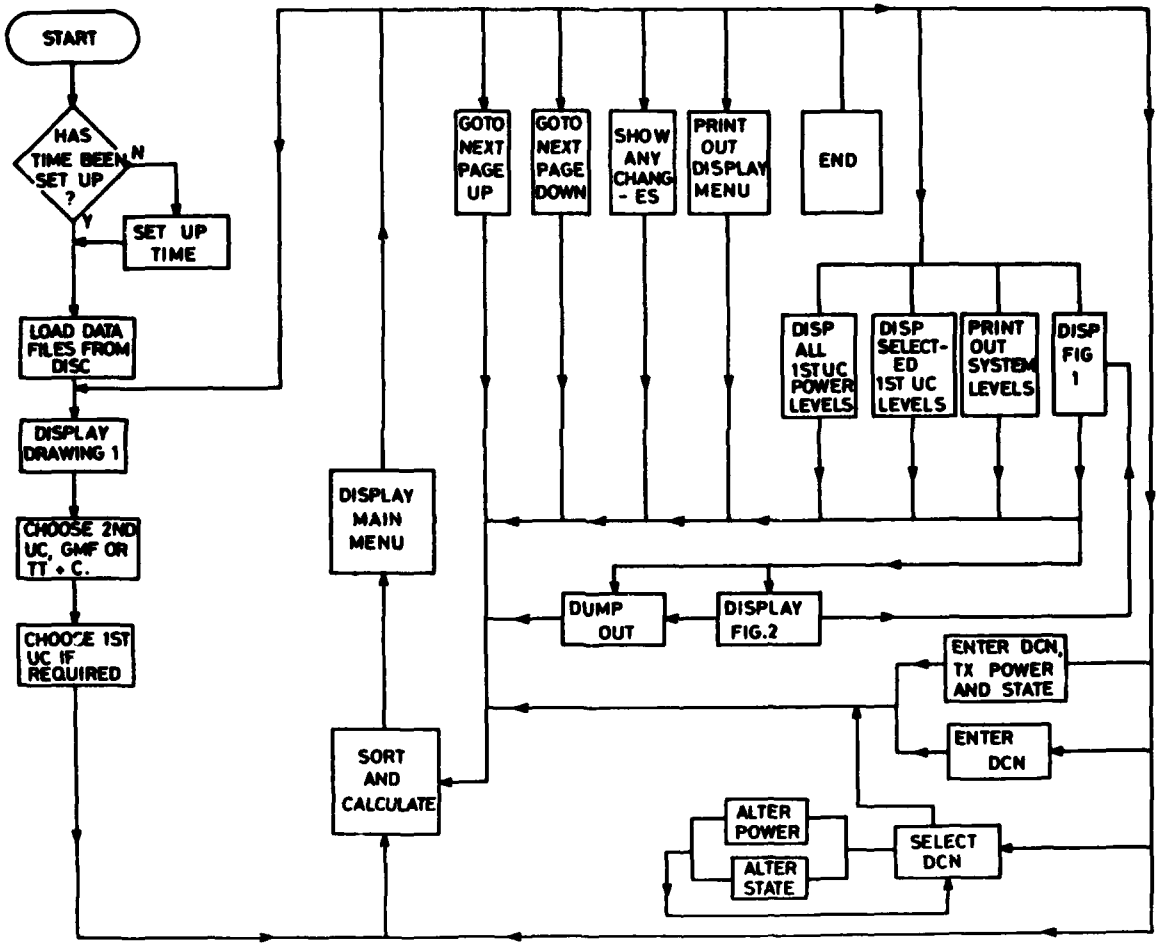


FIGURE. 2 FLOWCHART

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Abstract

The engineering of a large Satellite Communications Ground Station (SGT) which provides multi-carrier operation is a complex activity involving the control and management of various resources including access frequency, access power and circuit connectivity.