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Spectrum/Orbit Utilization Program for Geostationary Satellites

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SPECTRUM/ORBIT UTILIZATION PROGRAM FOR GEOSTATIONARY SATELLITES

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ABSTRACT

Mutual interferences among geostationary satellite communication systems determine the permitted spacing between satellites and the limits on the capacity of the orbit/spectrum resources available. This paper describes the "Spectrum/Orbit Utilization Program," a computer program for analyzing the mutual interferences among communication satellite systems. Capabilities of the program are described. Inputs, models used, program operations, and program outputs are given. To show application of the program, an example scenario is analyzed for fixed satellites providing domestic service to North America.

INTRODUCTION

Current and projected demands on the use of the geostationary orbit/spectrum resource require an analytic tool for determining the interferences among operating and planned communications systems. Prior to development of a satellite system, a detailed analysis must be performed to determine the expected interference environment during operations. Such calculations determine the permitted spacing between satellites and the limits on the capacity of a particular orbit/spectrum segment.

The Spectrum/Orbit Utilization Program (SOUP) is an analytic computer program for determining the mutual interferences among many geostationary satellite communication systems operating in a given scenario. The major computed outputs are the carrier-to-interference ratios at specified earth station receiver sites. This information allows the determination of the acceptability of planned communication systems.

Development of the SOUP analysis program has occurred over the last fourteen years. In 1970 (ref. 1), an early version became operational for evaluation of the general interference problem in satellite communications. In 1971 (ref. 2), the program was adapted for evaluation of the initial DOMSAT applications in the United States. Until 1981, the program underwent a series of minor modifications and improvements (ref. 3). Then in late 1981, SOUP was selected to be the analysis program used at the 1983 Regional Administrative Radio Conference for the broadcasting satellite service at 12 GHz in the western hemisphere. A number of major modelling changes were made, and inputs and outputs were modified to interface with other programs and the several data bases used at the Conference. The current version of SOUP (SOUP5 Version 3.8) is described in a technical manual and a users' manual (refs. 4 and 5).

This paper gives an overview of the SOUP analysis program. The basic capabilities of the program are described. The inputs required, the models used, program operations, and the outputs produced are summarized. Application and use of the program are shown by the presentation of an example analysis of a scenario for the fixed satellite service for North America.

CAPABILITIES OF THE ANALYSIS PROGRAM

SOUP calculates interferences and computes the communications impacts of those interferences. For the general situation depicted in Fig. 1, the feederlink carrier-to-interference ratio (C/I) is calculated at each satellite. At each earth station receive point, the downlink C/I is calculated, taking into account interferences from all other satellites in the geostationary orbit. Of course, only those satellites operating at nearby frequencies are entered into the scenario.

The program, as presently configured, can handle up to 300 downlink service areas and 300 feederlink service areas, where each service area pair is associated with a satellite in the geostationary orbit. The downlink service area and the feederlink service area associated with a single satellite are not required to be the same. There can be up to 1600 feederlink transmitter sites and 4500 earth station receiving sites. Dimensions of the arrays in the program can be increased at the expense of additional memory requirements and longer run times.

When the total C/I is calculated at an earth station receiver, account is taken of interferers that are co-channel, adjacent channel, and second

adjacent channel. Downlink and feederlink inter-
ferences are mathematically combined, and the
total interference is compared to a given re-
quirement that varies with modulation type, grade
of service, and other parameters. Earth station
receivers that exceed the required C/I are said
to have a positive margin, those that fail to
meet the requirement have a negative margin.

For some systems, communications performance
may be specified in terms other than C/I, e.g.,
picowatts of noise added to a telephone channel
or bit error rate in a digital system. In these
cases, a receiver transfer constant is used to
transform from a C/I ratio to an output perform-
ance measure.

The calculations performed for each test
point have technical parameters that are vari-
able for each service area. Rain attenuation
and other propagation effects can be taken into
account. Either circular or linear polarization
can be used. Additional quantities calculated
include power flux-density, received power, re-
ceived carrier-to-noise ratio, and spacecraft
power.

PROGRAM DESCRIPTION

The SOUP analysis program acts upon a number
of input data files, performs calculations, and
produces the outputs that indicate the mutual
interferences in the satellite systems under con-
sideration. The system overview of the program
is Fig. 2. Subsequent sections will discuss the
inputs, the mathematical models used, operations,
and the outputs.

SOUP is written in FORTRAN and has been
found to be easily transferable from machine to
machine. It has been run on IBM 370, VAX,
PRIME-400, and SIEMENS computers. Full details
of the program are given in Refs. 4 and 5.

Inputs

To run the program, complete descriptions
are required for the satellite communication
systems. Elements needed are shown in Tables I
and II. The listings in the tables are not in-
tended to be exhaustive, but rather they are com-
plete enough to show the high degree of detail
needed to specify a scenario for analysis. If
the required input data are not known, good
engineering judgment can be used as the basis
for assumed values.

Inputs can be specified on a global basis,
where, for example, all earth station receivers
might have the same characteristics. However,
provisions are made for overrides, whereby param-
eter values may be specified differently at each
location which allows, for example, different
antenna sizes or noise figures at different
locations.

Some of the required input data is computer
generated outside of SOUP. For example, the user
may desire to cover selected service areas on the
earth with minimum area elliptical beams. Char-
acteristics of the ellipses may be generated by
a separate program (ref. 6) and then stored in
the up and down ellipse files for use as inputs
to SOUP.

Modeling Used

In this section, an overview is given of the
mathematical models used in the SOUP analysis
program. It is intended only to convey a general
understanding of the program elements and to
indicate the flexibility of the models. Conse-
quently, full details are not given. Reference 4
gives more complete documentation of the models.

Geometric Models Spherical geometry is
used to calculate parameters such as slant
range, elevation angle, and the antenna off-axis
angles as shown in Fig. 3. If a ground point
and a satellite are determined to be over the
horizon with respect to each other, no
interference calculations are performed.

Antenna pointing errors are taken into
account by increasing the off-axis angle by the
pointing error when carrier signals are calcu-
lated, and by decreasing the off-axis angle when
interferences are calculated. This results in
conservative or worst-case calculations of (C/I)
ratios. Rotational errors of elliptical antennas
are not modelled.

Antenna Gain Patterns Antenna beams are
assumed to be either elliptical or circular and
may be specified by either their half power beam-
widths or diameters. Co-polarized and cross-
polarized gains are both modelled. A typical
antenna gain characteristic is shown in Fig. 4.
The segments of the off-axis gain curves of the
type shown in Fig. 4 are mathematically modelled
as constants, polynomials, exponential functions,
or logarithmic functions. Antenna gain charac-
teristics may also be input as gain contours on
the surface of the earth (for satellite antennas)
and as range measured antenna characteristics in
spherical coordinates.

In the case of an elliptical spacecraft
antenna, the off-axis gain is calculated by first
determining an equivalent half power beamwidth in
the off-axis direction. Then the gain is com-
puted by using that half power beamwidth in the
appropriate antenna gain model.

Protection Ratios In a communication sys-
tem, the protection ratio is defined as the ratio
at the receiver input of the wanted signal power
to the aggregate interfering signal power re-
quired to meet a given quality of service. The
protection ratio varies as a function of wanted
and interfering signal types, the modulations
used, the frequency difference between wanted and
interfering signals, and a number of other param-
eters. In the SOUP program, the protection ratio
can be modelled as a template (fig. 5 is typical)
or as discrete values for the co-channel, adja-
cent channel, and second adjacent channel inter-
ference cases.

Transmit Power Space station and feederlink
transmit powers may be specified in terms of
EIRP, Watts delivered to the antenna, resultant
power flux density, or resultant carrier-to-
noise ratio. For whatever form is specified, the
other parameters are calculated and supplied to
the user.

Propagation Model The current CCIR propagation model is incorporated as a subroutine. Other propagation models are available as options. Rain attenuation and depolarization are used in SOUP. Calculations may be run either for clear weather or for propagation effects taken into account, i.e., with rain.

Rain attenuation is used to calculate transmitter powers required, while both rain attenuation and depolarization effects are used to calculate received powers.

C/I calculations are done on a worst case basis. For feederlinks, faded C and unfaded I are assumed. For the downlink, at a particular earth station receiver site, both the C and the I are assumed to experience fading. The magnitude of the fade for each, of course, depends on the elevation angle to the source.

Channelization Calculations in SOUP may be performed for individual channels or for groups of channels. For individual channels, exact center frequencies are used, while for groups of channels, a typical frequency is used.

Aggregate and Total Interference and Margin Interferences are calculated in five categories: co-channel, upper and lower adjacent channel, and upper and lower second adjacent channel. Within each category, multiple interferers are assumed to add on a power basis to form the aggregate interference in that category. The aggregate uplink C/I and the aggregate downlink C/I are combined to form the total aggregate C/I in a category.

Each category has a protection ratio associated with it. The difference between the C/I and the protection ratio is the protection margin. Thus, a total aggregate co-channel protection margin is calculated. To combine all interference effects, the total aggregate equivalent protection margin M is calculated.

$$ M = -10 \, \log \left[\sum_{i=1}^{5} 10^{-(M_i/10)} \right] \quad \text{(dB)} \qquad (1) $$

where

M_1 total aggregate co-channel protection margin, in dB.

M_2, M_3 total aggregate adjacent channel protection margins for the upper and lower adjacent channels respectively, in dB.

M_4, M_5 total aggregate second adjacent channel protection margins for the upper and lower second adjacent channels respectively, in dB.

The adjective "equivalent" indicates that the protection margins for all interference sources from the adjacent and second adjacent channels as well as co-channel interference sources have been included.

Interference Matrix An interference matrix is available to allow the inhibiting of interference calculations between systems serving selected service areas. This feature is useful in removing from the calculations interference

situations that might be solved by other means such as, bilateral coordination.

Program Operations
The block diagram in Fig. 2 shows three major program elements P1, P2, and P3. Their functions are:

P1 - Selects the data from the data base which are needed for the run and assembles them into a form usable by programs P2 and P3; echo prints the selected data while checking and editing them for completeness and consistency.

P2 - Performs "non-cross" calculations: unit conversions (e.g., dB to numerics); transformation to Cartesian coordinates; calculations of protection ratios by interference category; determination of interference categories by channel; computations of on-axis gains, transmitter power, etc.

P3 - Performs "cross" calculations (i.e., for up, each satellite vs. all feederlink test points; for down, each earth station receiver test point vs. all satellites). Calculations performed include: gain, received signal power, attenuation, C/I and margins. Produces summary aggregate interference reports for up, down, and total.

Program Outputs
Major outputs of the SOUP program include (a) summary reports of the interference for feederlinks, downlinks, and total, (b) detailed reports giving results for each link calculation performed (all test points in all service areas), and (c) the binary output report which contains all input data and all calculated results (used for generating as yet unspecified output reports). An example summary report is given in Table III and segments of detail reports 1 and 2 are given in Table IV. (The numerical results given in Tables III and IV are for a fixed satellite service scenario discussed in the next section of this paper.)

USES AND APPLICATIONS OF THE PROGRAM
The SOUP analytic program was used as the official analysis program at the 1983 Regional Administrative Radio Conference (RARC). In that capacity, the program calculated the performances of tentative systems to allow evaluations of the suitability of alternative spectrum/orbit plans. Currently, the program is being used by the International Frequency Registration Board for a channel by channel analysis of the RARC-83 plan. Additionally the U.S. delegation to RARC-83 used SOUP to evaluate different planning alternatives prior to and during the Conference. The FCC, NTIA, NASA, and several communications satellite related corporations used and are continuing to use SOUP for mutual interference analyses of communication satellite systems.

As an example of current applications of the SOUP analysis program, a scenario in the fixed satellite service will be evaluated. The scenario considers domestic satellite service to North America (United States, Canada, and Mexico). While the satellite locations may be near to what is currently operational or

planned, the actual details of real satellites were not included. Common assumptions were made for the different satellite systems to simplify data entry. Table V lists the major assumed characteristics.

The summary of results in Table III shows for each test point, in each service area the C/I for co-channel, adjacent channel, and second adjacent channel interferers. The positive total margins indicate acceptable operation for the C/I criterion used. Where the margins are slightly negative, the C/I criterion has not been met, and slightly degraded performance will occur.

The detail reports in Table IV give values for specific parameters in the link calculations, e.g., carrier to noise ratio, received power flux density, antenna gains, transmitter power, and slant range.

CONCLUDING REMARKS

This paper has given an overview of the Spectrum/Orbit Utilization Program (SOUP) for analyzing the mutual interferences among communication systems having satellites in geostationary orbits. Capabilities of the program were described. Inputs, models used, program operations, and program outputs were given. Application of the program was shown by analyzing an example scenario in the fixed satellite service for domestic service within North America.

REFERENCES

1. "Orbit/Spectrum Utilization Study," Volume IV, General Electric, Document No. 70SD 4293, 31 December 1970

2. "Spectrum Orbit Utilization Program, User's Manual," by P. Sawitz and N. Shusterman, 16 May 1974, ORI Technical Report 830.

3. "Spectrum/Orbit Utilization Program User and Programmer's Manual," Volumes I and II, Davidson, J. and Sawitz, P., ORI, Contract NAS3-22884, 9 September 1981

4. "Spectrum Orbit Utilization Program Documentation, SOUP5 Version 3.8 Technical Manual," Davidson, J., Ottey, H.R., Sawitz, P. and Zusman, F.S., ORI. Prepared under Contract No. NAS3-22885 for NASA LeRC, 7 December 1983

5. "Spectrum Orbit Utilization Program Documentation, SOUP5 Version 3.8 User's Manual," Volumes I and II, Davidson, J., Ottey, H.R., Sawitz, P. and Zusman, F.S., ORI Tech. Rpt. No. 2273. Prepared under Contract No. NAS3-22885 for NASA LeRC, 29 June 1984.

6. "A Method for Determining the Minimum Elliptical Beam of a Satellite Antenna," Akima, H., NTIA Report 81-88, October 1981

TABLE I. – INPUT CHARACTERISTICS REQUIRED FOR DOWNLINKS

```
System Characteristics:
  Type of Modulation
  Frequency Band
  Number of Channels
  Necessary Bandwidth
  Channel Spacing
  Guard Bands
    Lower Band Edge
    Upper Band Edge
  Carrier to Noise Ratio
    (xx percent of worst month)
  Power Flux Density
    (Edge of coverage area,
     for xx percent of worst month)
  Protection Ratio
    (Required overall carrier-to-interference
     ratio for xx percent of worst month)
        Co-Channel
        Adjacent Channel
        Second Adjacent Channel

Satellite Characteristics:
  Satellite Orbital Position
  Transponder RF Power
    (Delivered to antenna input)
  EIRP Difference Between Beam Axis
    and Edge-of-Coverage
  Polarization
  Transmitting Antenna Reference Pattern
  Transmitting Antenna Efficiency
  Pointing Accuracy of Satellite Antenna

Receive Station Characteristics:
  Receiving Antenna Half-Power-Beamwidth
  Receiving Antenna Polarization
  Receiving Antenna Reference Pattern
  (System Noise Temperature)
  Latitude, Longitude, Elevation
  Rain Zone
```

TABLE II. – INPUT CHARACTERISTICS REQUIRED FOR FEEDERLINKS

```
System Characteristics:
  Type of Modulation
  Frequency Band
  Number of Channels
  Necessary Bandwidth
  Channel Spacing
  Guard Bands
    Lower Band Edge
    Upper Band Edge
  Carrier to Noise Ratio
    (xx percent of worst month)
  Protection Ratio
    (Required overall carrier-to-interference
     ratio for xx percent of worst month)
        Co-Channel
        Adjacent Channel
        Second Adjacent Channel

Feederlink Transmitter Characteristics:

  Transmit Power, Delivered to Antenna Input
  Transmit Antenna Diameter
  Transmit Antenna Polarization
  Transmit Antenna Reference Pattern
  Transmit Antenna Efficiency/Gain
  Feederlink EIRP
  Transmit Antenna Pointing Accuracy
  Latitude, Longitude, Elevation
  Rain Zone

Satellite Characteristics:
  Receive Antenna Half-Power Beamwidth
  Receive Antenna Polarization
  Receive Antenna Reference Pattern
  Receive Antenna Efficiency
  Receive Antenna Pointing Accuracy
  Satellite Receive Noise Temperature
```

TABLE III. – AGGREGATE TOTAL SUMMARY FOR FSSNAMO2

SERVICE AREA	SAT LONG	TEST POINT LAT-LONG	CO-CHANNEL C/I	MARGN	UPPER-ADJ C/I	MARGN	LOWER ADJ C/I	MARGN	NEXT-UPPER C/I	MARGN	LOWER ADJ C/I	MARGN		TOTAL MARGIN
CANT0001	-104.5	70.0 -141.0	19.1	-0.9	99.0	99.0	99.0	99.0	-3.0	16.9	-3.0	17.0	***	-1.0
	-104.5	70.0 -64.8	18.8	-1.2	99.0	99.0	99.0	99.0	-3.0	16.9	-3.0	17.0	***	-1.3
	-104.5	47.0 -52.5	19.1	-0.9	99.0	99.0	99.0	99.0	-3.0	16.9	-3.0	17.0	***	-1.1
	-104.5	43.0 -60.0	18.8	-1.2	99.0	99.0	99.0	99.0	-3.0	16.9	-3.0	17.0	***	-1.4
	-104.5	41.7 -82.6	18.5	-1.5	99.0	99.0	99.0	99.0	-3.0	16.9	-3.0	17.0	***	-1.6
	-104.5	44.6 -81.2	19.0	-1.0	99.0	99.0	99.0	99.0	-3.0	16.9	-3.0	17.0	***	-1.1
	-104.5	49.0 -106.0	19.2	-0.8	99.0	99.0	99.0	99.0	-3.0	16.9	-3.0	17.0	***	-0.9
	-104.5	48.3 -123.9	18.7	-1.3	99.0	99.0	99.0	99.0	-3.0	16.9	-3.0	17.0	***	-1.4
	-104.5	52.6 -132.2	19.0	-1.0	99.0	99.0	99.0	99.0	-3.0	16.9	-3.0	17.0	***	-1.1
	-104.5	60.3 -141.0	19.2	-0.8	99.0	99.0	99.0	99.0	-3.0	16.9	-3.0	17.0	***	-1.0
CANT0001	-108.0	70.0 -141.0	18.8	-1.2	99.0	99.0	99.0	99.0	-3.0	16.9	-3.0	17.0	***	-1.3
	-108.0	70.0 -64.8	18.3	-1.7	99.0	99.0	99.0	99.0	-3.0	16.9	-3.0	17.0	***	-1.8
	-108.0	47.0 -52.5	19.0	-1.0	99.0	99.0	99.0	99.0	-3.0	16.9	-3.0	17.0	***	-1.2
	-108.0	43.0 -60.0	18.9	-1.1	99.0	99.0	99.0	99.0	-3.0	16.9	-3.0	17.0	***	-1.2
	-108.0	41.7 -82.6	18.9	-1.1	99.0	99.0	99.0	99.0	-3.0	16.9	-3.0	17.0	***	-1.2
	-108.0	44.6 -81.2	19.2	-0.8	99.0	99.0	99.0	99.0	-3.0	16.9	-3.0	17.0	***	-1.0
	-108.0	49.0 -106.0	19.3	-0.7	99.0	99.0	99.0	99.0	-3.0	16.9	-3.0	17.0	***	-0.8
	-108.0	48.3 -123.9	19.0	-1.0	99.0	99.0	99.0	99.0	-3.0	16.9	-3.0	17.0	***	-1.1
	-108.0	52.6 -132.2	19.1	-0.9	99.0	99.0	99.0	99.0	-3.0	16.9	-3.0	17.0	***	-1.1
	-108.0	60.3 -141.0	19.0	-1.0	99.0	99.0	99.0	99.0	-3.0	16.9	-3.0	17.0	***	-1.1
CANT0001	-111.5	70.0 -141.0	20.9	0.9	99.0	99.0	99.0	99.0	-3.0	16.9	-3.0	17.0	***	0.7
	-111.5	70.0 -64.8	20.2	0.2	99.0	99.0	99.0	99.0	-3.0	16.9	-3.0	17.0	***	-0.0
	-111.5	47.0 -52.5	20.5	0.5	99.0	99.0	99.0	99.0	-3.0	16.9	-3.0	17.0	***	0.3
	-111.5	43.0 -60.0	20.5	0.5	99.0	99.0	99.0	99.0	-3.0	16.9	-3.0	17.0	***	0.3
	-111.5	41.7 -82.6	20.8	0.8	99.0	99.0	99.0	99.0	-3.0	16.9	-3.0	17.0	***	0.6
	-111.5	44.6 -81.2	21.0	1.0	99.0	99.0	99.0	99.0	-3.0	16.9	-3.0	17.0	***	0.8
	-111.5	49.0 -106.0	21.1	1.1	99.0	99.0	99.0	99.0	-3.0	16.9	-3.0	17.0	***	0.9
	-111.5	48.3 -123.9	19.9	-0.1	99.0	99.0	99.0	99.0	-3.0	16.9	-3.0	17.0	***	-0.2
	-111.5	52.6 -132.2	20.4	0.4	99.0	99.0	99.0	99.0	-3.0	16.9	-3.0	17.0	***	0.2
	-111.5	60.3 -141.0	20.8	0.8	99.0	99.0	99.0	99.0	-3.0	16.9	-3.0	17.0	***	0.6

TABLE IV. - DETAIL REPORTS

(a) Detail report number 1

DETAIL REPORT # 1 FOR FSSNAM02 DOWN   MAX C/I = 300.00

* SERVICE AREA * INTFERED INTFRING	SAT LONG DEG-E	* EARTH STA * LAT DEG-N	LONG DEG-E	C/I DB	C/N DB	PFD DB W/SQM	RVC"D POWER DBW	***** GND-CO DB	ANTENNA GND-X DB	GAINS ** SAT-CO DB	EQUIV GAIN DB	INTRF CAT	POL
CANT0001 CANT0001	-104.5	70.0	-141.0	10.48	-125.26	-115.06	43.53	0.00	28.03	71.56	0.00	CARRIER	CO
CANT0001	-104.5	70.0	-141.0	10.20	-125.26	-115.06	43.53	0.00	28.03	71.56	0.00	NN YY	CO
CANT0001	-108.0	70.0	-141.0	22.42	-124.26	-137.47	20.27	0.00	28.94	49.21	0.00	NN YY	CO
CANT0001	-111.5	70.0	-141.0	30.42	-124.40	-133.14	12.58	0.00	29.00	41.61	0.00	NN YY	CO
MEXT0001	-113.5	70.0	-141.0	51.69	-143.24	-166.75	9.83	0.00	12.97	22.82	0.00	NN YY	CO
MEXT0001	-116.5	70.0	-141.0	54.80	-143.34	-165.93	6.68	0.00	12.97	19.84	0.00	NN YY	CO
USACON01	-93.5	70.0	-141.0	38.90	-128.90	-155.96	7.55	0.00	23.99	31.55	0.00	NN YY	CO
USACON01	-96.0	70.0	-141.0	32.31	-128.33	-147.37	14.39	0.00	23.96	38.35	0.00	NN YY	CO
USACON01	-98.5	70.0	-141.0	26.31	-128.11	-147.37	20.24	0.00	24.17	44.41	0.00	NN YY	CO
USACON01	-101.0	70.0	-141.0	43.46	-128.68	-151.25	3.77	0.00	23.88	27.74	0.00	NN YY	CO
USACON01	-120.0	70.0	-141.0	26.14	-128.77	-159.95	2.13	0.00	24.74	26.03	0.00	NN YY	CO
USACON01	-122.5	70.0	-141.0	45.07	-129.24	-159.84	-0.71	0.00	24.36	24.36	0.00	NN YY	CO
USACON01	-125.0	70.0	-141.0	47.07	-129.34	-163.13	-0.79	0.00	23.92	23.16	0.00	NN YY	CO
USACON01	-128.0	70.0	-141.0	48.36	-129.34	-163.13	-0.79	0.00	23.92	23.16	0.00	NN YY	CO

(b) Detail report number 2

DETAIL REPORT # 2 FOR FSSNAM02 DOWN   MAX C/I = 300.00

* SERVICE AREA * INTFERED INTFRING	RAIN ATN DB	X-POL DISC DB	CANT ANGLE DEG	ELEV ANGLE DEG	OFF-AXIS ANGLE* E.STA DEG	ANGLE* SAT DEG	SLNT RANGE 10**6 M	*ON-AXIS GAIN* E.STA DB	SAT DB	REL POL ANGLE DEG	FREQ GHZ	RN ZN	ANT-BMWIDTH E.S. DEG	SAT DEG	SM BK
CANT0001 CANT0001	0.00	-99.90	7.33	0.109	3.380	40.872	43.66	30.95	0.00	3.920	A	1.09	7.19	N
CANT0001	0.00	-99.90	7.33	0.109	3.380	40.872	43.66	30.95	0.00	3.920	A	1.09	7.19	N
CANT0001	0.00	-99.90	8.05	3.503	3.221	40.794	43.66	31.03	0.00	3.920	A	1.09	7.85	N
CANT0001	0.00	-99.90	8.72	3.123	3.221	40.722	43.66	31.16	0.00	3.920	A	1.09	7.54	N
MEXT0001	0.00	-99.90	9.55	12.304	5.631	40.685	43.66	32.97	0.00	3.920	A	1.09	4.10	N
MEXT0001	0.00	-99.90	9.55	12.304	5.908	40.633	43.66	33.12	0.00	3.920	A	1.09	4.06	N
USACON01	0.00	-99.90	11.394	8.632	4.296	41.160	43.66	29.49	0.00	3.920	A	1.09	5.24	N
USACON01	0.00	-99.90	8.060	6.066	3.425	41.089	43.66	29.51	0.00	3.920	A	1.09	5.45	N
USACON01	0.00	-99.90	5.33	3.996	3.745	41.022	43.66	29.51	0.00	3.920	A	1.09	5.03	N
USACON01	0.00	-99.90	6.55	4.943	4.557	40.579	43.66	29.51	0.00	3.920	A	1.09	5.61	N
USACON01	0.00	-99.90	10.37	18.534	4.943	40.546	43.66	30.10	0.00	3.920	A	1.09	6.70	N
USACON01	0.00	-99.90	10.64	21.134	5.096	40.516	43.66	30.32	0.00	3.920	A	1.09	6.75	N
USACON01	0.00	-99.90	10.92	24.255	5.117	40.487	43.66	30.58	0.00	3.920	A	1.09	6.83	N
USACON01	0.00	-99.90	0.17	23.867	2.656	41.559	43.66	30.58	0.00	3.920	A	1.09	4.09	N

TABLE 5

A DOMESTIC SATELLITE SCENARIO FOR NORTH AMERICA

PARAMETER	VALUE
U.S. SATELLITE LOCATIONS	93.5, 96, 98.5, 101, 120, 122.5, 125, 128
CANADA SATELLITE LOCATIONS	104.5, 108, 111.5
MEXICO SATELLITE LOCATIONS	113.5, 116.5
SERVICE AREAS	MINIMUM AREA ELLIPSES THAT COVER EACH COUNTRY
FREQUENCIES	6 GHz, FEEDERLINK
	4 GHz, DOWNLINK
PK – PK FREQUENCY DEVIATION	24 MHz
NECESSARY BANDWIDTH	36 MHz
CHANNEL SPACING	40 MHz, SAME POL.; 20 MHz, OPP. POL.
PROTECTION RATIOS	20 DB, CO-CHANNEL
	12 DB, ADJACENT CHANNEL
	-20 DB, SECOND ADJACENT CHANNEL
FEEDERLINK TRANSMITTER ANTENNA	5 M., DIAMETER
	CCIR REFERENCE PATTERN, 32-25 LOG Ø
SATELLITE ANTENNA	REQUIRED ELLIPSE, RECEIVE AND TRANSMIT
	CCIR REFERENCE PATTERN, RPT. 558-2
SATELLITE ANTENNA BEAM EDGE LOSS	3 DB
EARTH STATION RECEIVE ANTENNA	5 M., DIAMETER
	CCIR REFERENCE PATTERN, 32-25 LOG Ø

The satellite location rows are grouped by a brace labeled: DEGREES WEST LONGITUDE

GEOSTATIONARY
SATELLITE
ORBIT

S_W

S_I

UPLINK

DOWNLINK

UPLINK INTERFERER

DOWNLINK INTERFERER

UPLINK

DOWNLINK

T

R

T

R

WANTED
SATELLITE
SYSTEM

T = TRANSMITTER
R = RECEIVER

INTERFERING
SATELLITE
SYSTEM
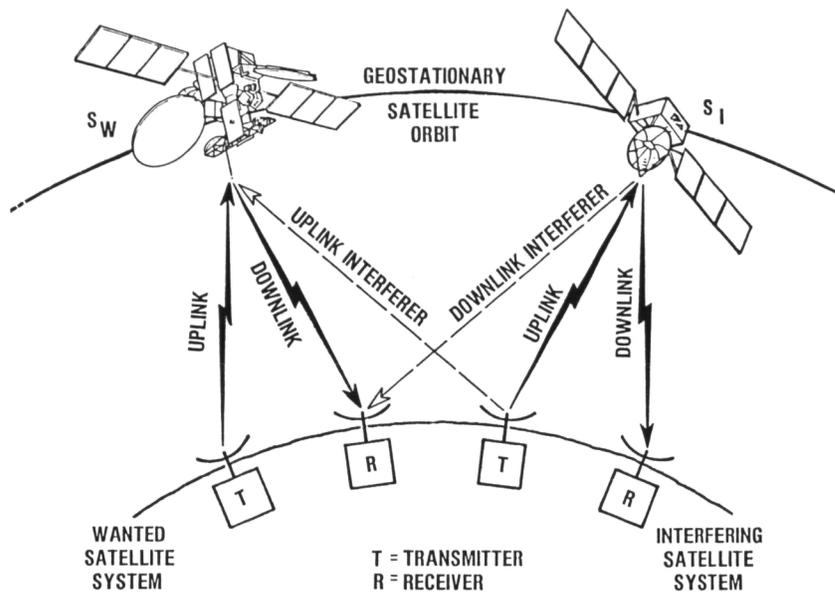
Figure 1. – Simplified model.

CARD IMAGE DATA BASE

ANALYSIS PROGRAMS CONTROL DATA

PART 1 (P1) PREPROCESSOR

INPUT DATA AND ERROR LISTING

BINARY FILE ECHO/DEBUG LISTINGS

BINARY FILE INTERFACE

PART 2 (P2) NON-CROSS CALCS AND CONVERSIONS

DIAGNOSTIC OUTPUTS

ERROR LISTING

BINARY FILE INTERFACE

PART 3 (P3) CROSS CALCULATIONS

DIAGNOSTIC OUTPUTS

SUMMARY AND AGGREGATE REPORTS

BINARY FILE INTERFACE

BINARY OUTPUT

Figure 2. - SOUP5 Overview.
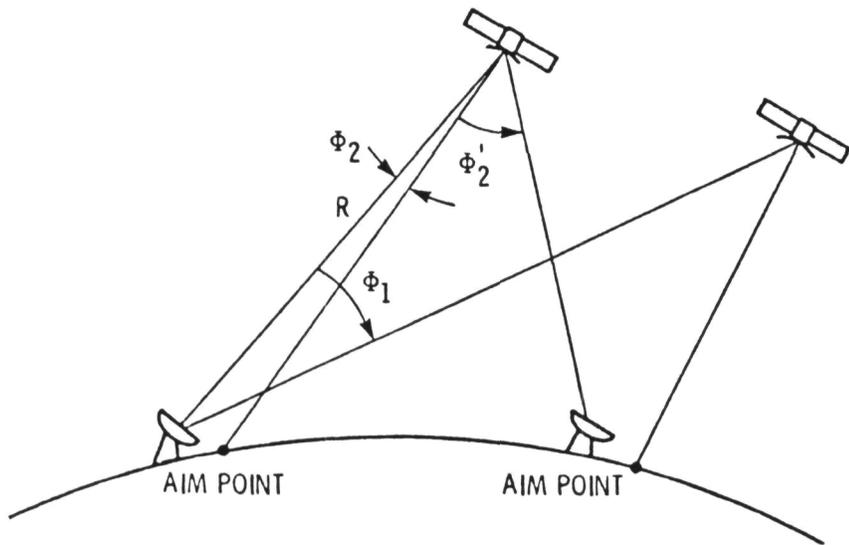
Figure 3. - Simplified geometry for calculation of range (R) and off-axis angles (Φ).

Φ_1 = Off-axis angle to non-target satellite.

Φ_2 = Off-axis angle to test point in desired service area.

Φ_2' = Off-axis angle to test point in non-target service area.
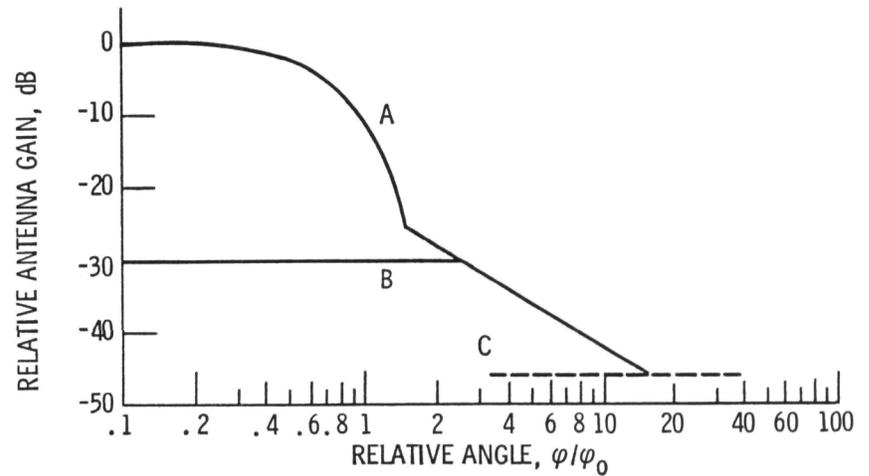
Figure 4. - Reference patterns for co-polar and cross-polar components for satellite transmitting antenna.

CURVE A: CO-POLAR COMPONENT (dB RELATIVE TO MAIN BEAM GAIN)

$-12(\varphi/\varphi_0)^2$ FOR $0 \leqslant (\varphi/\varphi_0) \leqslant 1.45$

$-(22 + 20 \log_{10}(\varphi/\varphi_0)$ FOR $1.45 < (\varphi/\varphi_0)$

AFTER INTERSECTION WITH CURVE C: AS CURVE C

CURVE B: CROSS-POLAR COMPONENT (dB RELATIVE TO MAIN BEAM GAIN)

-30 FOR $0 \leqslant (\varphi/\varphi_0) \leqslant 2.51$

AFTER INTERSECTION WITH CO-POLAR PATTERN: AS CO-POLAR PATTERN

CURVE C: MINUS THE ON-AXIS GAIN
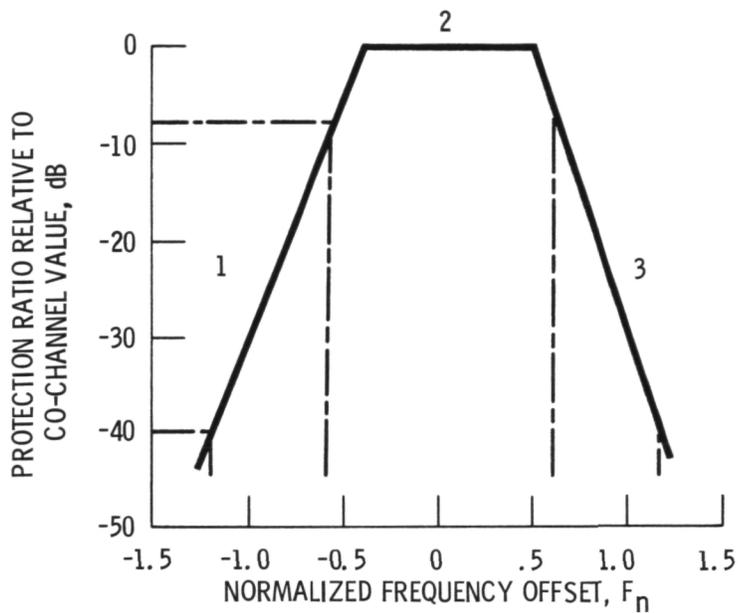
Figure 5. - Protection ratio template.

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16. Abstract

Mutual interferences among geostationary satellite communication systems determine the permitted spacing between satellites and the limits on the capacity of the orbit/spectrum resources available. This paper describes the "Spectrum/Orbit Utilization Program," a computer program for analyzing the mutual interferences among communication satellite systems. Capabilities of the program are described. Inputs, models used, program operations, and program outputs are given. To show application of the program, an example scenario is analyzed for fixed satellites providing domestic service to North America.

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