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RADIO FREQUENCY INTERFERENCE PREDICTION PROGRAM FOR EARTH-ORBITING SATELLITES

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OCTOBER 1967

GODDARD SPACE FLIGHT CENTER

GREENBELT, MARYLAND

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ABSTRACT

The increasing number of earth-orbiting satellites, transmitting in the 136-138 MHz band, has crowded this allocated frequency region utilized by the National Aeronautics and Space Administration's (NASA) Space Tracking and Data Acquisition Network (STADAN). STADAN ground stations sometimes experience radio frequency interference (RFI), caused by the appearance of two or more interfering satellites with overlapping 136 MHz emission spectrums, located simultaneously within view of a given ground station antenna.

Satellite orbits can be determined at least one-week ahead; therefore, an a-priori RFI prediction can be made that permits re-scheduling of station operations during restrictive periods when RFI is present. A computer-controlled satellite RFI prediction technique, employing the UNIVAC 1108 digital computer, has been developed that predicts interference one-week in advance for up to 50 satellites and 50 stations.

Computer inputs for the satellites include center frequency, spectral bandwidth, radiated power level, and Brouwer Mean elements for orbit determination. Tracking station inputs include antenna radiation patterns, both mainlobe and sidelobes, that are segmented in one-degree increments. Satellite-orbit data points, and station-received satellite signal-to-interference ratios, are computed at two-minute intervals. Station RFI reports show good agreement with predictions.

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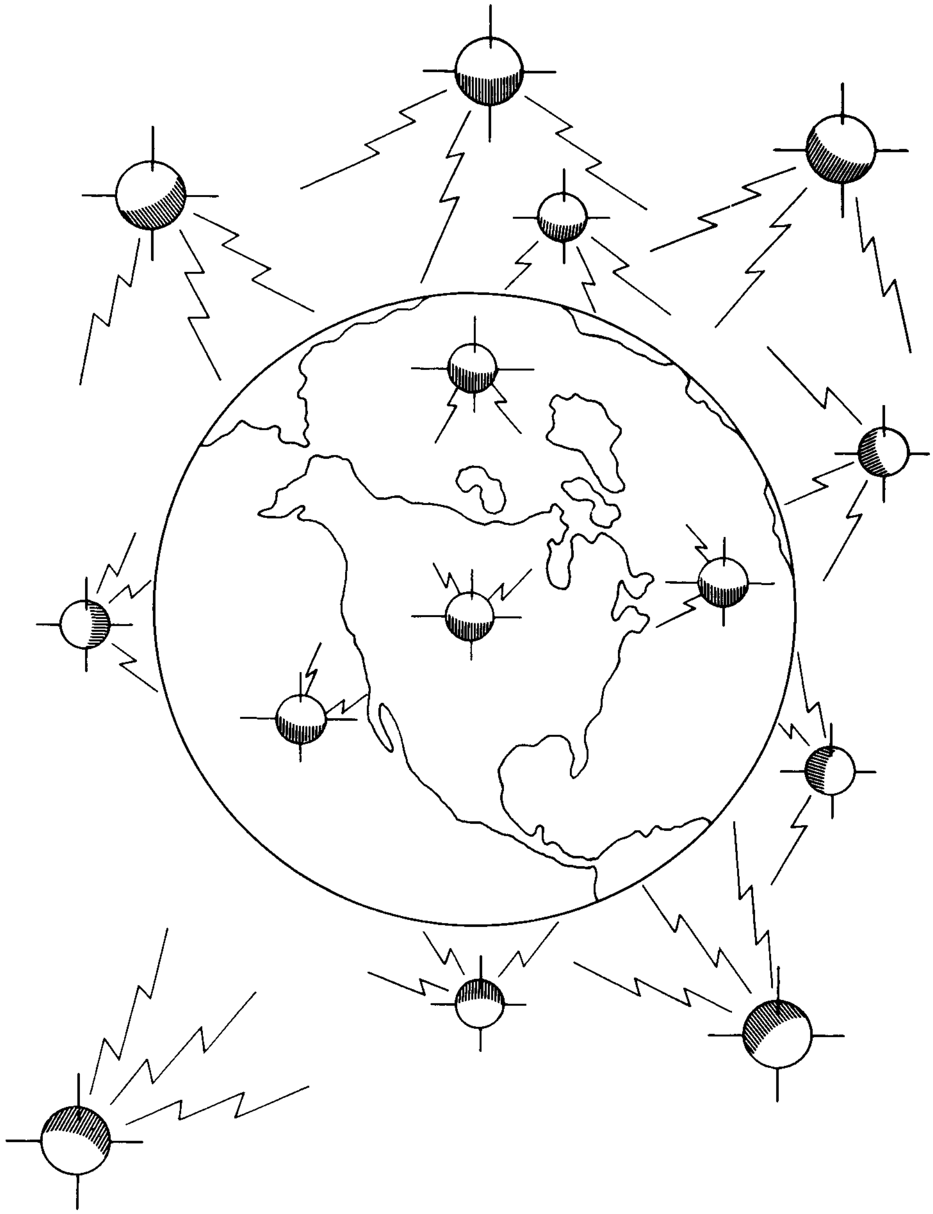


Frontispiece

RADIO FREQUENCY INTERFERENCE

PREDICTION PROGRAM FOR EARTH-ORBITING SATELLITES

by

Ralph E. Taylor

Goddard Space Flight Center

INTRODUCTION

The increasing number of earth-orbiting satellites, transmitting in the 136-138 MHz band, has crowded this allocated frequency region utilized by the National Aeronautics and Space Administration's (NASA) Space Tracking and Data Acquisition Network (STADAN). The 35-odd operational satellites, currently supported by STADAN, emit tracking and data acquisition radio signals in the 136-138 MHz band. The ground stations at times experience radio frequency interference (RFI), due to the appearance of two or more interfering satellites having overlapping 136 MHz emission spectrums, located simultaneously within view of a given ground station antenna. Department of Defense (DOD), other U. S. Government agency and foreign nation satellites, radiating 136 MHz signals, also add to the RFI problem.

A majority of the STADAN station RFI, presently being experienced, is caused by interference from satellites that can be predicted in advance. This is opposed to a minority of random electromagnetic compatibility type interference that occurs in an unpredictable manner.

A control center operator currently employs a satellite visibility chart, that is computer-generated, in conjunction with a satellite frequency listing to resolve certain RFI conflicts. This report describes an automated computer program for performing essentially the same function with increased speed and accuracy. Also, the program calculates the received signal-to-interference (S/I) ratio for all visible satellites in addition to making orbit computations.

Computer inputs include satellite emitted frequency, spectral bandwidth and radiated power level. Also inputted are the station geodetic coordinates (longitude, latitude and height), receiving system threshold sensitivities, receiving antenna radiation patterns, and Brouwer Mean Satellite orbital elements. The program utilizes the UNIVAC 1108 high-speed digital computer written in FORTRAN IV format. The UNIVAC 1108 computer was selected since a Brouwer Mean orbit generator software program had already been developed for this computer. The high speed and relatively large memory capacity (65,000 cores) were also required.

Certain phases of the UNIVAC 1108 computer program are based upon the deterministic interference prediction technique, described by Haber[1], that calculates the signal-to-interference (S/I) ratio at a given station. Reference 2, on the other hand, determines all visible satellites from orbit computation, but does not consider the S/I ratio.

The RFI prediction program described in this paper can handle only Brouwer Mean orbital elements. A future modification of the program will take into account orbits using other than Brouwer Mean elements. Also, the program will be expanded for other frequencies including the 400-401 MHz and 401-402 MHz space bands.

The RFI prediction program, described in this report, is based upon an initial study effort performed by the University of Pennsylvania, The Moore School of Electrical Engineering (Reference 1), Philadelphia, Pa.; and a subsequent computer programming effort by the Wolf Research and Development Corporation (Reference 3), Applied Sciences Department, Bladensburg, Md.

DESCRIPTION OF CONCEPT

Since the satellite orbits can be predicted at least one-week ahead, an RFI prediction can be made which makes possible in-advance re-scheduling of station operations during restrictive periods when RFI is present. In addition, inferior data taken during an interference interval can be identified at the station resulting in data handling cost and manpower savings.

For a steerable antenna, the satellite being tracked is assumed positioned perfectly within the ground station antenna beam (see Figure 1); whereas, the interfering satellite, i, injects an un-

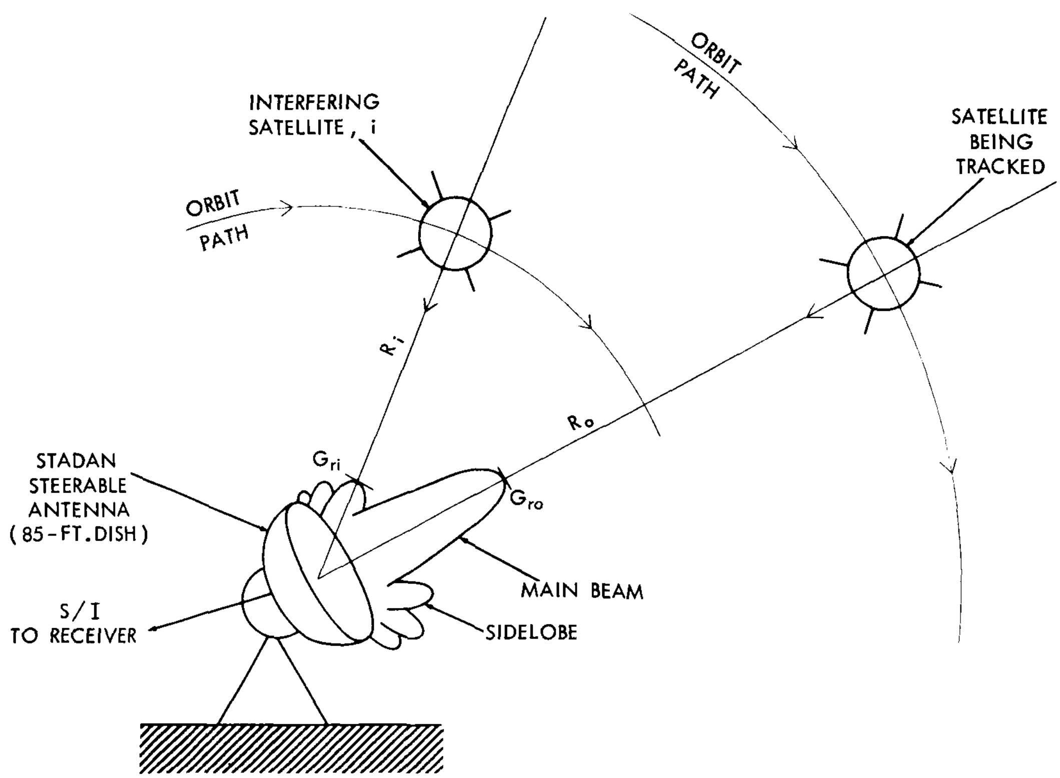


Figure 1—Radio-link parameters for satellite interference prediction program.

desired signal either by transversing the main beam or cutting a high-level sidelobe. The desired received signal power, S, and interfering signal power, I, are determined from

$$S = \frac{P_{to} \, G_{to} \, G_{ro} \, \lambda_0^2}{(4\pi R_0)^2} . \tag{1}$$

$$f_0 = \frac{c}{\lambda_0}$$

$$I = \frac{P_{ti} \, G_{ti} \, G_{ri} \, \lambda_i^2}{(4\pi R_i)^2} . \tag{2}$$

$$f_i = \frac{c}{\lambda_i} , \qquad c = \text{velocity of light} ,$$

assume

$$G_{ti} = G_{to} = 1.$$

Range, R_0, is the independent variable in (1), for a given satellite, assuming an omnidirectional transmit antenna gain, $G_{to} = 1$, constant transmitted power, P_{to}, fixed wavelength, λ_0, and using a steerable ground antenna with a maximum pattern gain, G_{ro}. On the other hand, the received interference power level, I, in (2) is affected by the antenna pattern gain variable, G_{ri}, variable range, R_i, and transmitter power, P_{ti}.

The satellite distance from a given ground station is determined at 2-minute intervals as part of the orbit computation for all satellites and ground stations. The appropriate satellite radio-link parameters are inserted into (1) and (2) and the station-received signal levels are then calculated. These levels are then compared to the threshold sensitivity for the particular receiving system. Levels below threshold are automatically eliminated. S/I ratios for all satellites, compared to the one being tracked, are then computed from (1) and (2). The magnitude of the S/I ratio, compared to a preset value, determines if interference is present or absent. An interference condition is defined as existing when the heuristic equality $S/I \leq +20$ db holds.

Prior to computing the S/I ratio, a satellite visibility search sub-routine eliminates satellites below a minimum restricted elevation angle (e.g., 10° and below), and a frequency search is made based on the criterion,

$$|f_0 - f_i| \leq \frac{B_0}{2} + \frac{B_i}{2} . \tag{3}$$

By definition, satellites can interfere that meet the (3) criterion.

The bandwidths, B_0 and B_i, in (3) are the emitted spectral bandwidths of the respective desired and interfering satellites; whereas, f_0 and f_i are the respective carrier center frequencies. An ideal, uniformly flat, emitted spectral bandwidth is assumed to simplify the computations. The emitted spectrum is assumed symmetrically centered about the carrier frequency. The frequency search identifies satellite transmitters as potential RFI sources when the (3) equality holds (i.e., overlapping spectrums).

The spectral width of an unmodulated carrier frequency is defined as 30 KHz (i.e., $f \pm 15$ KHz) to account for uncertainties in transmitter frequency, Doppler shift, etc. The assumed spectral bandwidth for each modulated signal ranges from 60 KHz to 200 KHz depending upon the particular modulation employed for a given satellite. These values have been made somewhat larger than the actual emitted spectrums to account for the injection of adjacent-channel interference in off-band skirt selectivity regions of the ground-station receiver IF amplifier.

This program utilizes the Brouwer Mean orbital elements to generate orbits at 2-minute intervals on a magnetic tape. This tape in turn is used in generating RFI predictions for a 24-hour period for up to 50 earth-orbiting satellites and 50 world-wide data acquisition stations. The stations include Minitrack, 85-ft. dish, 40-ft. dish, VHF range and range rate, SATAN (satellite automatic tracking antenna) and 9-element yagi-array antennas. The computer input also includes the satellite identification number, radiated power level, transmitter frequency, emitted spectrum bandwidth, and ground station antenna radiation pattern data.

Each STADAN world-wide tracking facility is actually comprised of several stations. The Rosman, N. C. facility, for example, has two 85-ft. dishes, a SATAN system and a VHF range rate system. RFI is separately predicted for each of the various receiving system types at a given site. A considerable saving in computation time, and quantity of RFI print-out data, has resulted by developing a standard "Model System" antenna radiation pattern for systems with similar antenna beamwidth and gain characteristics. Such a "Model System" was developed that represents the SATAN, VHF range and range rate, 40-ft. dish and 9-element yagi antennas in STADAN.

ORBIT ANALYSIS

Satellite ephemeris calculations[3] in the RFI prediction program are based on the Brouwer[4] general perturbations method.

A Brouwer general perturbations orbit generator calculates the time-independent quantities, osculating orbital elements, and the inertial rectangular coordinates of a satellite at a given time. The zonal harmonics are accounted for, and orbit-drag terms are considered. The computations are referenced to the right ascension of Greenwich at January 0.0 of the year of the start of the run.

x_s, y_s, and z_s are the rectangular coordinates of the satellite in inertial space with the x-axis pointing toward the vernal equinox, the z-axis pointing toward the North Pole, and the y-axis forming a right-handed system. After computing the inertial rectangular coordinates of each satellite with the Brouwer orbit generator, the earth-fixed rectangular coordinates (X_s, Y_s and Z_s) of each satellite are computed from

$$X_s = (x_s + y_s)^{½} \cos \lambda_s .$$

$$Y_s = (x_s + y_s)^{½} \sin \lambda_s . \quad .$$

$$Z_s = z_s .$$

where

λ_s is the satellite's east longitude ,

$$\lambda_s = \arc \tan \left(\frac{y_s}{x_s}\right) - \theta_g ,$$

and θ_g is the right ascension of Greenwich.

The earth-fixed rectangular coordinates (X_{ob}, Y_{ob} and Z_{ob}) are computed for each station from the geodetic latitude, Φ, of the station (antenna); east longitude, γ; and height, h, of the station above the reference ellipsoid according to,

$$X_{ob} = (h + v) \cos \Phi \cos \gamma$$

$$Y_{ob} = (h + v) \cos \Phi \sin \gamma$$

$$Z_{ob} = \left[h + v \left(1 - E^2\right)\right] \sin \Phi$$

Where

$$v = \frac{a_e}{\left(1 - E^2 \sin^2 \Phi\right)^{½}}$$

$$E^2 = 1 - \frac{b_e^{\,2}}{a_e^{\,2}} ,$$

and

a_e is the earth's equatorial radius
b_e is the earth's polar radius.

The local east ($\hat{E}$), north ($\hat{N}$), and vertical ($\hat{Z}$) vectors are computed for each station from,

$$\hat{E} = - \sin \gamma \hat{i} + \cos \gamma \hat{j} + 0 \hat{k}$$

$$\hat{N} = - \sin \Phi \cos \gamma \hat{i} - \sin \Phi \sin \gamma \hat{j} + \cos \Phi \hat{k}$$

$$\hat{Z} = \cos \Phi \cos \gamma \hat{i} + \cos \Phi \sin \gamma \hat{j} + \sin \Phi \hat{k} .$$

Satellite visibility calculations are made for each time point, for each station, and for each satellite. Defining the station-satellite range vector as,

$$\bar{R} = D_x \hat{i} + D_y \hat{j} + D_z \hat{k}$$

where

$\hat{i}$, $\hat{j}$ and $\hat{k}$ are the respective x, y and z unit vectors ,

$$D_x = X_s - X_{ob}$$

$$D_y = Y_s - Y_{ob}$$

$$D_z = Z_s - Z_{ob} .$$

The sine of the elevation angle, EL , is computed from,

$$\sin(EL) = \frac{\bar{R} \cdot \hat{Z}}{|\bar{R}|} ,$$

$\bar{R} \cdot \hat{Z}$ is the dot product of the range and vertical vectors and, $|\bar{R}| = \left(D_x^2 + D_y^2 + D_z^2\right)^{1/2}$ = magnitude of range vector. All satellites, below the station's minimum elevation angle of 10°, are ignored. Finally, the earth-fixed station-satellite unit vector is

$$\hat{U} = \frac{\bar{R}}{|\bar{R}|} .$$

For an X - Y axis antenna mount (see Figure 2), the X and Y angles are determined from

$$X = \arctan\left[\frac{\hat{U} \cdot \hat{E}}{\hat{U} \cdot \hat{Z}}\right]$$

$$Y = \arcsin(\hat{U} \cdot \hat{N})$$

$$\Phi = \arctan\left[\frac{\hat{U} \cdot \hat{N}}{\hat{U} \cdot \hat{E}}\right]$$

$$\theta = \cos(\hat{U} \cdot \hat{Z})$$

The angle off the North-Zenith plane for the minitrack system, with a stationary antenna pattern, is defined as (see Figure 3)

$$\alpha = \arctan\left[\frac{\hat{U} \cdot \hat{E}}{\hat{U} \cdot \hat{Z}}\right],$$

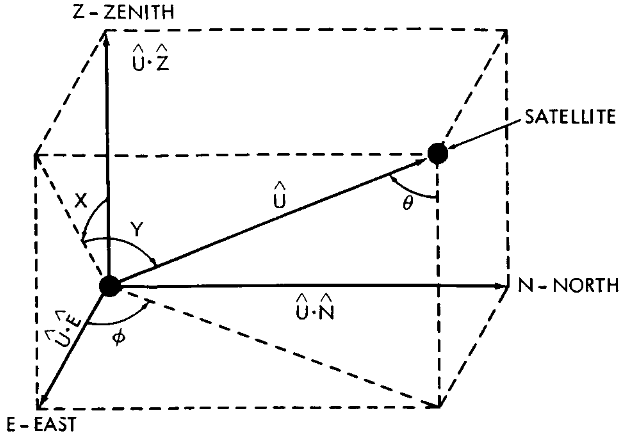


Figure 2—Local coordinate system for steerable x-y axis antenna.

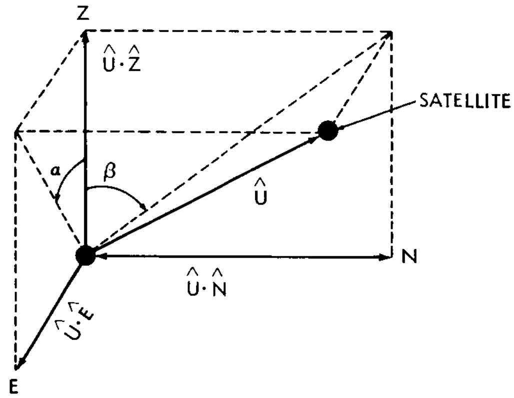


Figure 3—Minitrack antenna fixed local coordinate system.

and the angle off the East-Zenith plane as

$$\beta = \text{arc tan} \left[\frac{\hat{U} \cdot \hat{N}}{\hat{U} \cdot \hat{Z}}\right].$$

The terms in parentheses are the dot products of the earth-fixed station unit vector, $\hat{U}$, and the respective direction.

For a steerable antenna with an X - Y mount, the satellite being tracked is assumed positioned perfectly within the main beam of the antenna. The angle of the j^{th} interfering satellite, off the x_j antenna axis, is determined from

$$\text{arc tan} \frac{y_j}{z_j} ,$$

and the angle off the y_j axis as

$$\text{arc tan} \frac{x_j}{z_j} .$$

COMPUTER PROGRAM

The UNIVAC 1108 computer program utilizes the following inputs:

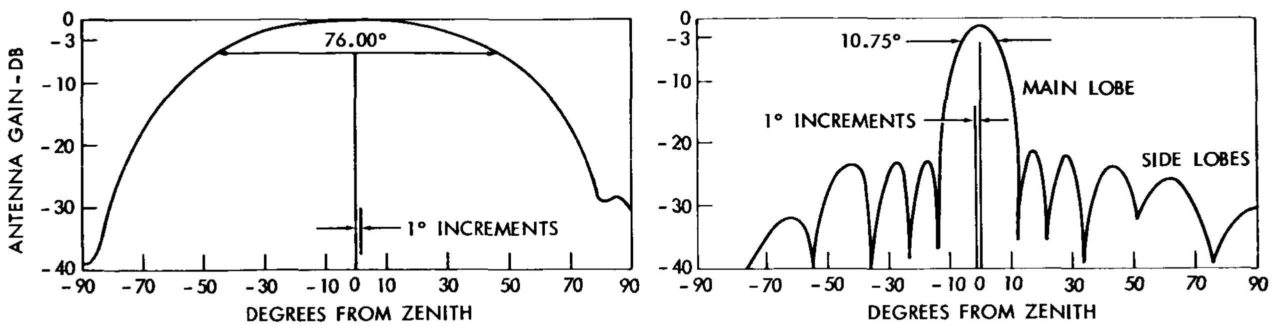
Satellite Parameters . . . . (a) Brouwer Mean orbital elements, epoch time, and drag terms.

(b) Transmit carrier frequency (maximum of 3 per satellite).

(c) Spectral bandwidth.

(d) RF power level.

Ground Station Parameters . . . .
(a) Geodetic coordinates.
(b) Antenna radiation patterns in 1° increments (see Figure 4 example).
(c) Restricted elevation angles (i.e., 10° and below).
(d) Receiving system threshold sensitivity.
(e) S/I criterion.



E-PLANE PATTERN H-PLANE PATTERN

Figure 4—136 MHz minitrack antenna patterns.

The above satellite and ground station parameters are entered on punched cards and read into the UNIVAC 1108 computer (see Figure 5 flow diagram). Each satellite orbit data point is computed at 2-minute intervals and the following computer functions then performed in the order listed below for each station:

(1) Satellite visibility search.
(2) Satellite frequency search.
(3) Calculation of received signal level and comparison with threshold sensitivity of system.
(4) Computation of S/I ratio and determination of RFI.

The UNIVAC 1108 computer then writes the RFI events at 2-minute intervals on magnetic tape (see Figure 5), and a station-ordered sort is thereafter performed to provide a summary and a detail listing of the predicted RFI events.

Another magnetic tape is prepared by the UNIVAC 1108 computer, for the Stromberg Carlson (SC) type SC 4020 plotter, that graphically plots both a summary and detailed display of the predicted RFI events for a single 24-hour period. The same data is available on both 35 mm film (for optical viewer) and 9-inch wide rolled-paper chart printouts.

The UNIVAC 1108 also writes a listing of the predicted RFI events on magnetic tape for the IBM 1401 or 360 type computer-printer. The latter equipment prints-out a tabulated (15 inches wide) IBM listing of the predicted RFI events identifying the satellites involved and their respective frequencies.

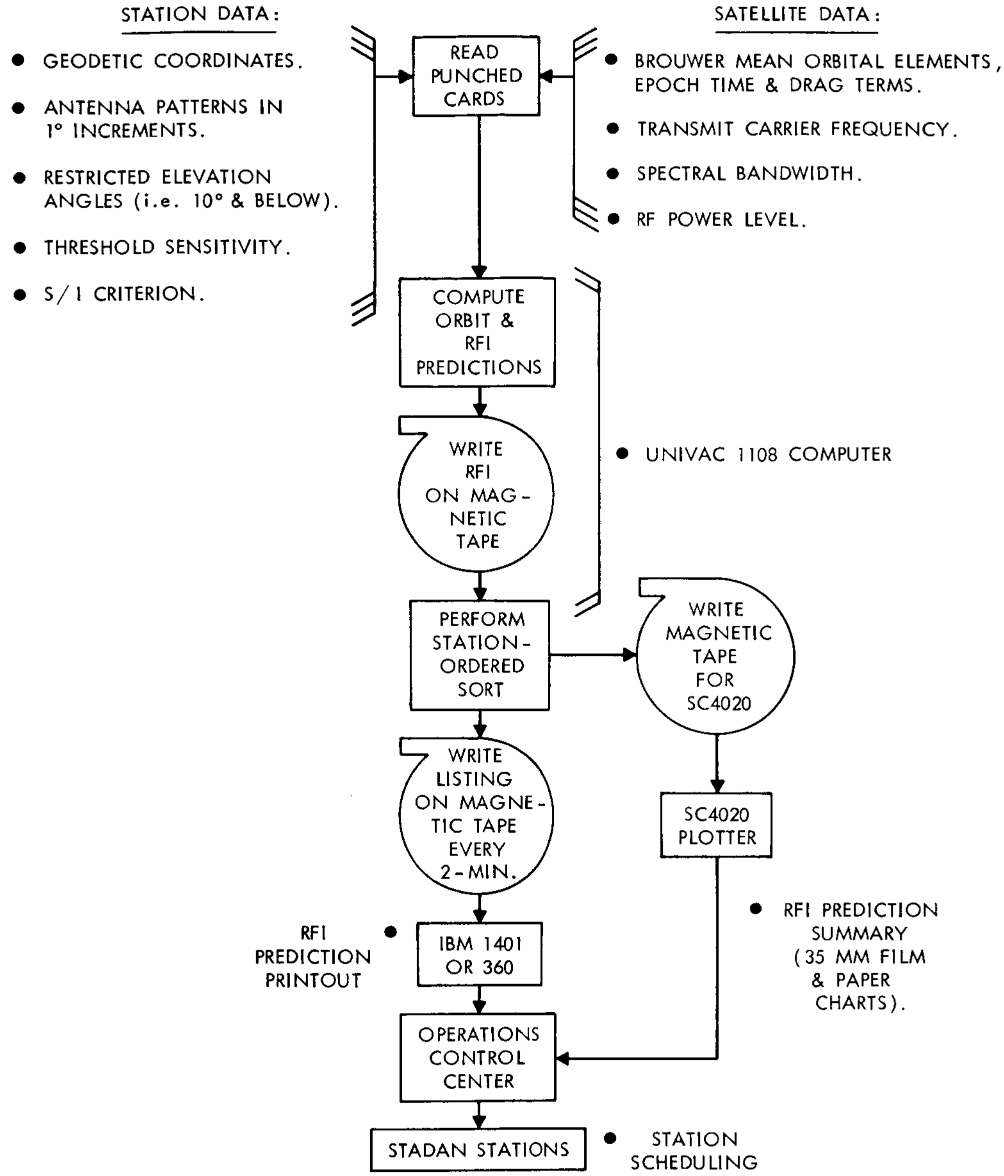


Figure 5—Flow diagram, satellite interference prediction computer program.

All three data forms (i.e., 35 mm film, SC 4020 chart-roll and IBM paper printout listing) are available as a data set, covering a given 24-hour period, for use in controlling STADAN scheduling. Seven (7) RFI prediction data sets (24-hrs. per set) are required to cover a seven (7) day week. A week's worth of RFI data can be run at one time. The total UNIVAC 1108 computer running time for the RFI prediction program is about one hour per week. This amount of computer time is not considered excessive for operational use. The RFI prediction program output data (SC 4020 plots and IBM 1401 printout) can be used by Operations Control Center personnel for determining clear-channel station scheduling.

DATA PRINT-OUT FORMAT

SC 4020 Plotter

The SC 4020 plotter output includes a summary bar chart (see Figure 6 example) which lists sequentially-numbered ground stations on the ordinate, and Zulu time on the abscissa in 1-hour increments from 0 to 24 hours. Each predicted RFI event is indicated by the printed symbol "I", and a solid black-bar section (made by repeatedly printing symbol "I") indicates continuous interference for that time period. The summary bar chart is useful for an initial "quick look" check to

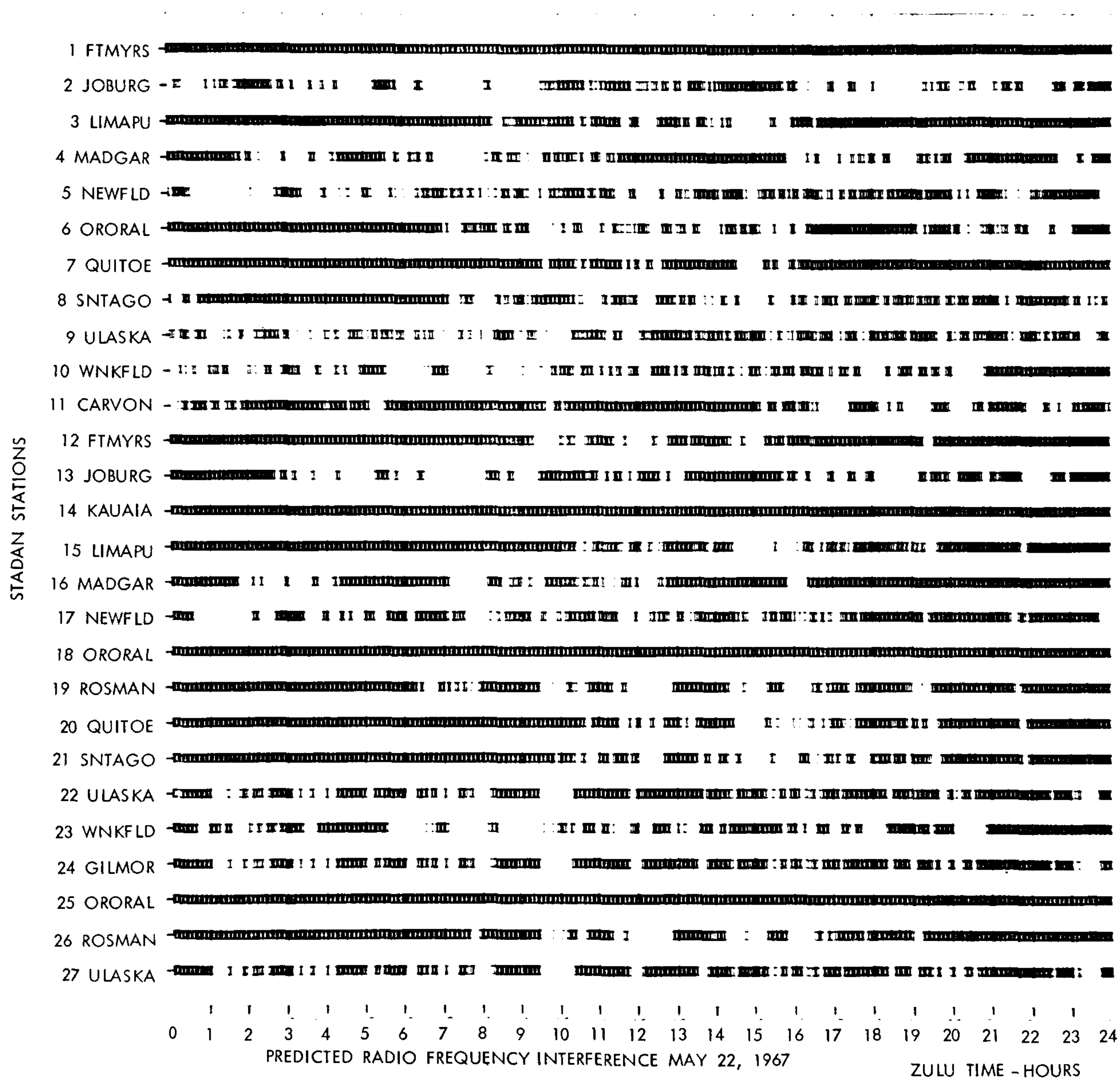


Figure 6—SC 4020 plotter summary of predicted satellite interference.

identify RFI regions in STADAN. Figure 6 gives the WORST CASE condition since the program assumes that all satellites continuously radiate. The indicated RFI, for a given station, represent contributions from all satellites in the program.

Detailed graphs are also available on the SC 4020 plotter printout that lists the abbreviated names of the satellites on the ordinate (sequentially numbered) and time from 0 to 24 hours on the abscissa (see Figure 7). The satellites involved in a particular RFI event are identified by a

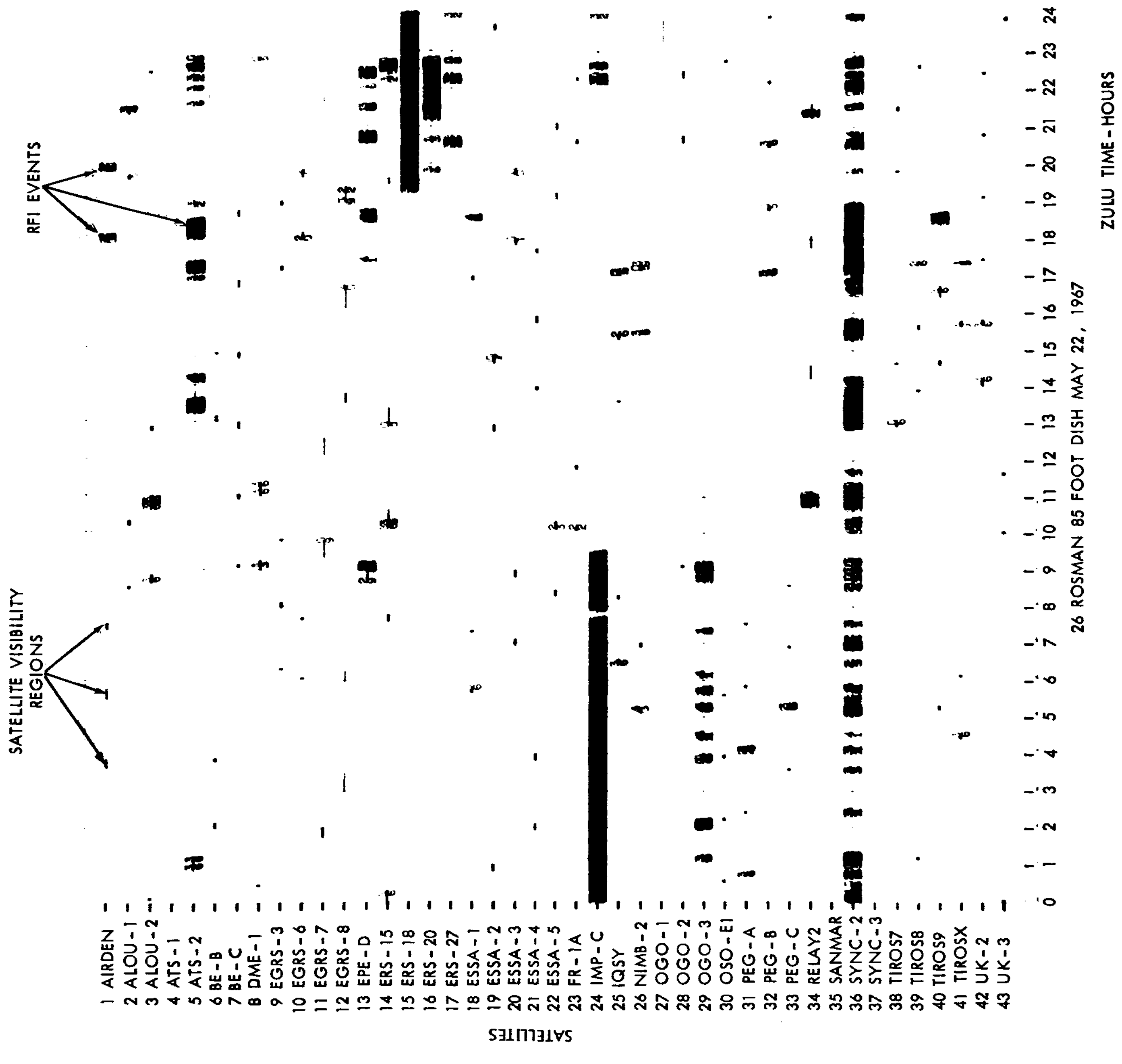


Figure 7–SC 4020 plotter detail display of predicted satellite interference.

vertically printed arabic number,* located opposite the satellite name abbreviation, at a particular time. A solid-bar section again indicates continuous RFI for that region.

The horizontal thin-line marked regions, sometimes appearing as dots on the detailed SC 4020 graph (Figure 7), indicate the period of time a particular satellite is visible over a given station. A satellite, by definition, must always be above the horizon to contribute in an RFI event at a given station. However, two or more satellites, simultaneously visible over a given station, may or may not contribute to an RFI event depending upon their frequency, and the resulting signal-to-interference (S/I) ratio. Using a station-scheduling criterion that eliminates passes for all visible satellites, that are close in frequency without regard for the S/I ratio, unnecessarily eliminates a significant amount of good satellite signal data.

The detailed SC 4020 graphs are sequentially listed wherein generic equipment types are grouped together for convenience in viewing (e.g., all Minitrack systems in sequence, 85-foot dish, etc.).

IBM 1401 or 360 Printout

The IBM 1401 or 360 Tabulated printout lists satellite input quantities to the computer (see Figure 8), input parameters for the tracking stations (Figure 9), and a typical printed-page listing of the predicted RFI events (see Figure 10).

SATELLITE INPUT QUANTITIES

			BROUWER MEAN ORBITAL ELEMENTS						TRANSMITTING CHARACTERISTICS		
SAT IDENT.	EPOCH YYMMDD	EPOCH HHMMSS	SEMI-MAJOR AXIS (M)	ECCEN	INCL	MEAN ANOMALY	ARG OF PERIGEE	RA OF NODE	POWER WATTS	FREQ (MHZ)	BND WTH (KHZ)
PEG-A	670426	0C0000	6988339	.015782	31.766	315.032	133.153	289.301	.100 .750	136.889 136.410	60. 120.
PEG-B	670423	CCC00C	6997593	.015376	31.776	219.647	229.682	198.114	.100 .750	136.889 136.410	60. 120.
PEG-C	670419	CC000C	6892794	.001622	28.889	61.607	180.235	11.633	.100 .750	136.592 136.410	60. 120.
RELAY2	670424	CC0000	11129457	.24C807	46.349	155.296	59.325	350.879	.250 .250	136.621 136.621	30. 120.
SANMAR	670426	101154	6862142	.038605	2.892	348.184	296.291	131.785	.100	136.740	30.
SYNC-2	670315	153439	42135819	.000386	30.356	359.312	.639	298.429	2.000 2.000 2.000	136.470 136.470 136.980	30. 120. 120.
SYNC-3	670315	195733	42161964	.000185	1.530	253.598	286.535	91.253	2.000 2.000 2.000	136.470 136.470 136.980	30. 120. 120.
TIROS7	670415	CC0000	7011365	.002122	58.232	193.019	123.529	107.082	.050 .050	136.233 136.921	120. 120.
TIROS8	670408	CC000C	7104856	.003455	58.497	86.115	173.884	162.191	.050 .050 5.000	136.232 136.924 136.924	120. 120. 120.
TIROS9	670425	0C0000	8018437	.116932	96.418	10.432	214.054	39.100	.050 .050	136.232 136.919	120. 120.
TIROSX	670425	CC000C	7164599	.006731	98.579	126.283	106.614	16.605	.050 .050	136.232 136.925	120. 120.
UK-2	670513	142912	6902538	.037001	51.639	183.950	176.413	23.093	.250	136.560	90.
UK-3	670505	16C932	6925857	.007641	80.182	352.600	172.108	170.082	.250	136.560	90.

Figure 8—Satellite input quantities to UNIVAC 1108 computer.

*e.g. $\genfrac{}{}{0pt}{}{1}{3}$ for 13.

TRACKING STATIONS

	NAME	TYPE	GEODETIC LAT DD MM SS	EAST LONG DD MM SS	HEIGHT (METERS)	MIN EL.	THRESH (DBM)	GAIN (DB)	S/I (DB)
1	FTMYRS	MINITRACK	26 32 53.52	278 8 3.89	3.7	10.0	-132.0	16.30	60.0
2	JOBURG	MINITRACK	-25 52 58.86	27 42 27.93	1521.0	10.0	-132.0	16.30	60.0
3	LIMAPU	MINITRACK	-11 46 36.49	282 50 58.18	49.1	10.0	-132.0	16.30	60.0
4	MADGAR	MINITRACK	-19 0 27.11	47 18 .47	1375.9	10.0	-132.0	16.30	60.0
5	NEWFLD	MINITRACK	47 44 29.05	307 16 43.24	63.4	10.0	-132.0	16.30	60.0
6	CRORAL	MINITRACK	-35 37 52.72	148 57 20.87	924.8	10.0	-132.0	16.30	60.0
7	QUITOE	MINITRACK	-0 37 21.75	281 25 14.77	3560.8	10.0	-132.0	16.30	60.0
8	SNTAGO	MINITRACK	-33 8 58.11	289 19 51.28	694.9	10.0	-132.0	16.30	60.0
9	ULASKA	MINITRACK	64 58 36.57	212 29 5.79	294.4	10.0	-132.0	16.30	60.0
10	WNKFLD	MINITRACK	51 26 44.12	359 18 14.62	65.5	10.0	-132.0	16.30	60.0
11	CARVON	MODEL SYSTEM	-24 54 14.66	113 42 56.02	11.6	10.0	-155.0	20.00	20.0
12	FTMYRS	MODEL SYSTEM	26 32 53.52	278 8 3.89	3.7	10.0	-155.0	20.00	20.0
13	JOBURG	MODEL SYSTEM	-25 52 58.86	27 42 27.93	1521.0	10.0	-155.0	20.00	20.0
14	KAUAIA	MODEL SYSTEM	22 7 26.55	202 19 50.97	1152.1	10.0	-155.0	20.00	20.0
15	LIMAPU	MODEL SYSTEM	-11 46 36.49	282 50 58.18	49.1	10.0	-155.0	20.00	20.0
16	MADGAR	MODEL SYSTEM	-19 0 27.11	47 18 .47	1375.9	10.0	-155.0	20.00	20.0
17	NEWFLD	MODEL SYSTEM	47 44 29.05	307 16 43.24	63.4	10.0	-155.0	20.00	20.0
18	ORORAL	MODEL SYSTEM	-35 37 52.72	148 57 20.87	924.8	10.0	-155.0	20.00	20.0
19	ROSMAN	MODEL SYSTEM	35 12 .71	277 7 41.23	878.7	10.0	-155.0	20.00	20.0
20	QUITOE	MODEL SYSTEM	-0 37 21.75	281 25 14.77	3560.8	10.0	-155.0	20.00	20.0
21	SNTAGO	MODEL SYSTEM	-33 8 58.11	289 19 51.28	694.9	10.0	-155.0	20.00	20.0
22	ULASKA	MODEL SYSTEM	64 58 36.57	212 29 5.79	294.4	10.0	-155.0	20.00	20.0
23	WNKFLD	MODEL SYSTEM	51 26 44.12	359 18 14.62	65.5	10.0	-155.0	20.00	20.0
24	CILMOR	85 FOOT DISH	64 58 42.67	212 30 18.05	308.8	10.0	-151.0	27.40	20.0
25	ORORAL	85 FOOT DISH	-35 37 52.72	148 57 20.87	924.8	10.0	-151.0	27.40	20.0
26	ROSMAN	85 FOOT DISH	35 12 .71	277 7 41.23	878.7	10.0	-151.0	27.40	20.0
27	ULASKA	85 FOOT DISH	64 58 36.57	212 29 5.79	294.4	10.0	-151.0	27.40	20.0

Figure 9—STADAN tracking station input quantities to UNIVAC 1108 computer.

```
                                 STATION      TYPE              DATE                        PAGE NUMBER   1
                                 FTMYRS     MINITRACK       MAY 22, 1967
                                                            INTERFERENCE
 TIME
HHMMSS

000000  * SYNC-2 (136.470) WITH ATS-1  (136.470) * SYNC-2 (136.470) WITH ATS-1  (136.470) * ATS-1  (136.470) WITH ERS-15 (136.439)
        * UK-3   (136.560) WITH ATS-1  (136.470) * SYNC-2 (136.980) WITH IMP-C  (136.916) * SYNC-2 (136.470) WITH ERS-15 (136.439)
        * ATS-1  (136.470) WITH SYNC-2 (136.470) * ATS-1  (136.470) WITH SYNC-2 (136.470) *
000200  * SYNC-2 (136.470) WITH ATS-1  (136.470) * SYNC-2 (136.470) WITH ATS-1  (136.470) * SYNC-2 (136.470) WITH ERS-15 (136.439)
        * ATS-1  (136.470) WITH ERS-15 (136.439) * ATS-1  (136.470) WITH SYNC-2 (136.470) * SYNC-2 (136.980) WITH IMP-C  (136.916)
        * ERS-15 (136.439) WITH SYNC-2 (136.470) * ATS-1  (136.470) WITH SYNC-2 (136.470) *
000400  * SYNC-2 (136.470) WITH ALOU-2 (136.587) * ATS-1  (136.470) WITH ALOU-2 (136.587) * SYNC-2 (136.470) WITH ATS-1  (136.470)
        * SYNC-2 (136.470) WITH ATS-1  (136.470) * SYNC-2 (136.470) WITH ERS-15 (136.439) * ATS-1  (136.470) WITH ERS-15 (136.439)
        * ALOU-2 (136.587) WITH SYNC-2 (136.470) * SYNC-2 (136.980) WITH IMP-C  (136.916) *
000600  * SYNC-2 (136.470) WITH ALOU-2 (136.587) * ATS-1  (136.470) WITH ALOU-2 (136.587) * SYNC-2 (136.470) WITH ATS-1  (136.470)
        * ERS-15 (136.439) WITH ATS-1  (136.470) * ATS-1  (136.470) WITH ERS-15 (136.439) * SYNC-2 (136.470) WITH ATS-1  (136.470)
        * SYNC-2 (136.980) WITH IMP-C  (136.916) * SYNC-2 (136.470) WITH ERS-15 (136.439) *
000800  * SYNC-2 (136.470) WITH ATS-1  (136.470) * ERS-15 (136.439) WITH ATS-1  (136.470) * ATS-1  (136.470) WITH ERS-15 (136.439)
        * SYNC-2 (136.470) WITH ATS-1  (136.470) * SYNC-2 (136.980) WITH IMP-C  (136.916) * SYNC-2 (136.470) WITH ERS-15 (136.439)
        * ATS-1  (136.470) WITH SYNC-2 (136.470) * ATS-1  (136.470) WITH SYNC-2 (136.470) *
001000  * SYNC-2 (136.470) WITH ATS-1  (136.470) * ERS-15 (136.439) WITH ATS-1  (136.470) * ATS-1  (136.470) WITH ERS-15 (136.439)
        * SYNC-2 (136.470) WITH ATS-1  (136.470) * SYNC-2 (136.980) WITH IMP-C  (136.916) * SYNC-2 (136.470) WITH ERS-15 (136.439)
        * ATS-1  (136.470) WITH SYNC-2 (136.470) * ATS-1  (136.470) WITH SYNC-2 (136.470) *
001200  * SYNC-2 (136.470) WITH ATS-1  (136.470) * SYNC-2 (136.470) WITH ATS-1  (136.470) * SYNC-2 (136.470) WITH ERS-15 (136.439)
        * ATS-1  (136.470) WITH ERS-15 (136.439) * ATS-1  (136.470) WITH SYNC-2 (136.470) * SYNC-2 (136.980) WITH IMP-C  (136.916)
        * ERS-15 (136.439) WITH SYNC-2 (136.470) * ATS-1  (136.470) WITH SYNC-2 (136.470) *
001400  * SYNC-2 (136.470) WITH ATS-1  (136.470) * SYNC-2 (136.470) WITH ATS-1  (136.470) * SYNC-2 (136.470) WITH ERS-15 (136.439)
        * ATS-1  (136.470) WITH ERS-15 (136.439) * ATS-1  (136.470) WITH SYNC-2 (136.470) * SYNC-2 (136.980) WITH IMP-C  (136.916)
        * ERS-15 (136.439) WITH SYNC-2 (136.470) * ATS-1  (136.470) WITH SYNC-2 (136.470) *
001600  * SYNC-2 (136.470) WITH ATS-1  (136.470) * SYNC-2 (136.470) WITH ATS-1  (136.470) * SYNC-2 (136.470) WITH ERS-15 (136.439)
        * ATS-1  (136.470) WITH ERS-15 (136.439) * ATS-1  (136.470) WITH SYNC-2 (136.470) * SYNC-2 (136.980) WITH IMP-C  (136.916)
        * ERS-15 (136.439) WITH SYNC-2 (136.470) * ATS-1  (136.470) WITH SYNC-2 (136.470) *
001800  * SYNC-2 (136.470) WITH ATS-1  (136.470) * SYNC-2 (136.470) WITH ATS-1  (136.470) * SYNC-2 (136.470) WITH ERS-15 (136.439)
        * ATS-1  (136.470) WITH ERS-15 (136.439) * ATS-1  (136.470) WITH SYNC-2 (136.470) * SYNC-2 (136.980) WITH IMP-C  (136.916)
        * ERS-15 (136.439) WITH SYNC-2 (136.470) * ATS-1  (136.470) WITH SYNC-2 (136.470) *
002000  * SYNC-2 (136.470) WITH ATS-1  (136.470) * SYNC-2 (136.470) WITH ATS-1  (136.470) * SYNC-2 (136.470) WITH ERS-15 (136.439)
        * ATS-1  (136.470) WITH ERS-15 (136.439) * ATS-1  (136.470) WITH SYNC-2 (136.470) * SYNC-2 (136.980) WITH IMP-C  (136.916)
        * ERS-15 (136.439) WITH SYNC-2 (136.470) * ATS-1  (136.470) WITH SYNC-2 (136.470) *
002200  * SYNC-2 (136.470) WITH ATS-1  (136.470) * ERS-15 (136.439) WITH ATS-1  (136.470) * ATS-1  (136.470) WITH ERS-15 (136.439)
        * SYNC-2 (136.470) WITH ATS-1  (136.470) * SYNC-2 (136.980) WITH IMP-C  (136.916) * SYNC-2 (136.470) WITH ERS-15 (136.439)
        * ATS-1  (136.470) WITH SYNC-2 (136.470) * ATS-1  (136.470) WITH SYNC-2 (136.470) *
002400  * SYNC-2 (136.470) WITH ATS-1  (136.470) * SYNC-2 (136.470) WITH ATS-1  (136.470) * ATS-1  (136.470) WITH SYNC-2 (136.470)
        * SYNC-2 (136.980) WITH IMP-C  (136.916) * IMP-C  (136.916) WITH SYNC-2 (136.980) * ATS-1  (136.470) WITH SYNC-2 (136.470)
002600  * SYNC-2 (136.470) WITH ATS-1  (136.470) * SYNC-2 (136.470) WITH ATS-1  (136.470) * ATS-1  (136.470) WITH SYNC-2 (136.470)
        * SYNC-2 (136.980) WITH IMP-C  (136.916) * IMP-C  (136.916) WITH SYNC-2 (136.980) * ATS-1  (136.470) WITH SYNC-2 (136.470)
002800  * SYNC-2 (136.470) WITH ATS-1  (136.470) * SYNC-2 (136.470) WITH ATS-1  (136.470) * ATS-1  (136.470) WITH SYNC-2 (136.470)
        * SYNC-2 (136.980) WITH IMP-C  (136.916) * IMP-C  (136.916) WITH SYNC-2 (136.980) * ATS-1  (136.470) WITH SYNC-2 (136.470)
003000  * SYNC-2 (136.470) WITH ATS-1  (136.470) * SYNC-2 (136.470) WITH ATS-1  (136.470) * ATS-1  (136.470) WITH SYNC-2 (136.470)
        * SYNC-2 (136.980) WITH IMP-C  (136.916) * IMP-C  (136.916) WITH SYNC-2 (136.980) * ATS-1  (136.470) WITH SYNC-2 (136.470)
003200  * SYNC-2 (136.470) WITH ATS-1  (136.470) * SYNC-2 (136.470) WITH ATS-1  (136.470) * ATS-1  (136.470) WITH SYNC-2 (136.470)
        * SYNC-2 (136.980) WITH IMP-C  (136.916) * IMP-C  (136.916) WITH SYNC-2 (136.980) * ATS-1  (136.470) WITH SYNC-2 (136.470)
003400  * SYNC-2 (136.470) WITH ATS-1  (136.470) * SYNC-2 (136.470) WITH ATS-1  (136.470) * ATS-1  (136.470) WITH SYNC-2 (136.470)
        * SYNC-2 (136.980) WITH IMP-C  (136.916) * IMP-C  (136.916) WITH SYNC-2 (136.980) * ATS-1  (136.470) WITH SYNC-2 (136.470)
003600  * SYNC-2 (136.470) WITH ATS-1  (136.470) * SYNC-2 (136.470) WITH ATS-1  (136.470) * ATS-1  (136.470) WITH SYNC-2 (136.470)
        * SYNC-2 (136.980) WITH IMP-C  (136.916) * IMP-C  (136.916) WITH SYNC-2 (136.980) * ATS-1  (136.470) WITH SYNC-2 (136.470)
003800  * SYNC-2 (136.470) WITH ATS-1  (136.470) * SYNC-2 (136.470) WITH ATS-1  (136.470) * ATS-1  (136.470) WITH SYNC-2 (136.470)
        * SYNC-2 (136.980) WITH IMP-C  (136.916) * IMP-C  (136.916) WITH SYNC-2 (136.980) * ATS-1  (136.470) WITH SYNC-2 (136.470)
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Figure 10—Typical IBM 1401 printout listing of predicted satellite interference.

The SC 4020 plotter output can be initially checked to determine "quick-look" RFI conditions in STADAN for a given projected 24-hr. period; whereas, the IBM printed-page (see Figure 10 example) can be consulted for an accurate time listing of the predicted RFI events. This listing includes Zulu Time (hours, minutes, seconds - HHMMSS), satellite abbreviated name, and corresponding carrier center frequency(s).

The existing UNIVAC 1108 computer RFI prediction program can handle up to a maximum of eight (8) RFI events at any one instant of time; therefore, there is an upper limit of eight (8) RFI events that can be printed for any given minute of time. Occasionally, the IBM printout lists two seemingly redundant RFI events during the same minute. This indicates two separate RFI events caused by broadband modulation, or a change in signal power level, for the same center frequency.

SATELLITE RFI PREDICTION TEST RESULTS

In order to check the program prediction accuracy, several trial-run RFI predictions have been made including both STADAN-supported and non-supported satellites. The initial computer run, made on March 29, 1967 with 33 satellites, verified four (4) out of eleven (11) station-reported RFI events involving satellites. In one instance, Santiago commanded-on ALOU-1, radiating on 136.077 MHz, while simultaneously tracking IMP-3 on 136.124 MHz. The two signals were close enough in frequency to cause interference, and the predictions revealed that ALOU-1 would interfere with IMP-3 from 29/0355Z to 0405Z. Santiago reported that RFI existed from 29/0352Z to 0400Z and further suspected ALOU-1 as the interfering source. This prediction program would eliminate future RFI events of this type by re-scheduling of passes.

A later prediction run, made on May 25, 1967 with 43 satellites, had an improved score wherein eight (8) out of eleven (11) satellite RFI reports were verified. A still later operational run, with participating Operations Center Branch (code 512) personnel, was made covering the period September 19-25, 1967 that included 40 satellites and 27 STADAN network stations. This run was more successful and resulted in a better score wherein 40 out of a possible 47, or 85%, of the station-reported RFI events were accurately predicted (see Table 1). The interference time intervals, as reported by the stations, agrees closely with the predicted time intervals. In several instances, the predictions reveal that three (3) satellites could have been involved in a single RFI event.

A rather large amount of potential interference is indicated by the SC 4020 summary chart (see Figure 6 typical excerpt). The RFI picture improves by observing a typical detailed display output, from the SC 4020 plotter (see Figure 7), that shows predicted interference for the 85-foot dish antenna at Rosman, N. C. The predicted interference is somewhat larger than actually exists in STADAN since the computer program assumes that all 136 MHz emitters are continuously radiating whether commandable or not.

Table 1

Forty (40) Predictions Verified by STADAN RFI Reports for September 19-25, 1967.

RFI Prediction	Station-Reported Interference Event
IQSY-1 (136.530) with ERS-18 (136.530) at 19/0118Z to 0120Z	IQSY-1 with ERS-18 at 19/0119Z (JOBURG)
ATS-2 (136.470) with ERS-18 (136.530) at 19/0758Z to 0940Z	Satellite RFI with ERS-18 at 19/0830Z to 0834Z (JOBURG)
RELAY-1 (136.140) with IMP-4 (136.140 at 19/0814Z to 0824Z	RELAY-1 with IMP-4 at 19/0816Z (JOBURG)
RELAY-1 (136.140) with IMP-4 (136.140) at 19/0444Z to 0550Z	RELAY-1 with IMP-4 at 19/0500Z to 0521Z (MADGAR)
NIMB-2 (136.497) with ERS-18 (136.530) at 19/1150Z to 1158Z	Satellite RFI with ERS-18 at 19/1151Z to 1159Z (JOBURG)
RELAY-1 (136.140) with IMP-4 (136.140) at 19/1100Z to 1144Z	RELAY-1 with IMP-4 at 19/1100Z to 1130Z (SANTIAGO)
ATS-2 (136.470) with ERS-18 (136.530) at 19/1158Z to 1236Z	Satellite RFI with ERS-18 at 19/1226Z to 1230Z (JOBURG)
ESSA-5 (136.770) with EGRS-7 (136.800) at 19/1710Z to 1720Z	Satellite RFI with EGRS-7 at 19/1709Z to end of pass (ALASKA)
FR-1A (136.800) with ESSA-2 (136.769) at 20/0054Z to 0102Z	Satellite RFI with ESSA-2 at 20/0100Z (LIMA PU)
ATS-2 (136.470) with ERS-18 (136.530) at 20/1130Z to 1304Z	Satellite RFI with ERS-18 at 20/1236Z to 1238Z (JOBURG)
DME-1 (136.380) with ERS-27 (136.380) at 20/1342Z to 1350Z	DME-1 with ERS-27 at 20/1342Z to 1347Z (JOBURG)
NIMB-2 (136.498) with ERS-18 (136.530) at 20/0400Z to 0408Z	NIMB-2 with ERS-18 at 20/0359Z to 0405Z (ORRORAL)
ESSA-4 (136.770) with ESSA-2 (136.769) at 20/0506Z to 0516Z	Satellite RFI with ESSA-2 at 20/0508Z (ALASKA)
PEG-C (136.591) with RELAY-2 (136.621) at 20/0846Z to 0850Z	RFI with RELAY-2 at 20/0844Z to 0845Z (SANTIAGO)
UK-3 (136.560) with IQSY-1 (136.530) at 21/0916Z to 0918Z	UK-3 with IQSY-1 at 21/0917Z (JOBURG)
IQSY-1 (136.530) with UK-3 (136.560) at 21/1056Z	IQSY-1 with UK-3 at 21/1054Z to 1056Z (JOBURG)
ERS-18 (136.530) with IQSY-1 (136.530) at 21/1056Z	UK-3 with IQSY-1 at 21/1050Z to 1059Z (JOBURG)
UK-3 (136.560) with IQSY-1 (136.530) at 21/1056Z	
RELAY-1 (136.140) with IMP-4 (136.140) at 21/0622Z to 0714Z	RFI with IMP-4 at 21/0615Z to 0628Z (MADGAR)
DME-1 (136.380) with ERS-27 (136.380) at 22/0412Z to 0416Z	Satellite RFI with ERS-27 at 22/0412Z to 0417Z (ORRORAL)
ALOU-1 (136.592) with ERS-18 (136.530) at 22/1606Z to 1608Z	Satellite RFI with ERS-18 at 22/1605Z to 1609Z (FT MYRS)
IQSY-1 (136.530) with ERS-18 (136.530) at 22/2316Z to 2322Z	IQSY-1 with ERS-18 at 22/2318Z to 2323Z (JOBURG)
ATS-2 (136.470) with ERS-18 (136.530) at 22/2322Z to 2326Z	
RELAY-1 (136.140) with IMP-4 (136.140) at 23/1412Z to 23/1414Z	RFI with IMP-4 at 23/1407Z to 1414Z (FT MYRS)
RELAY-1 (136.140) with IMP-4 (136.140) at 23/1734Z to 1754Z	RFI with IMP-4 at 23/1736Z to 1748Z (FT MYRS)
UK-3 (136.560) with ERS-18 (136.530) at 23/1948Z to 1954Z	Satellite RFI (UK-3) with ERS-18 at 23/1951Z to 1956Z (ALASKA)
ALOU-2 (136.587) with ERS-18 (136.530) at 23/1956Z to 2004Z	
ESSA-1 (136.918) with TIROS-7 (136.921, at 23/1702Z	RFI with TIROS-7 at 23/1701Z to 1703Z (SANTIAGO)
FR-1A (136.800) with ESSA-5 (136.770) at 24/0108Z to 0112Z	Satellite RFI with ESSA-5 at 24/0105Z to 0114Z (ALASKA)
IQSY-1 (136.530) with ERS-18 (136.530) at 24/0740Z to 0744Z	IQSY-1 with ERS-18 at 24/0742Z to 0746Z (JOBURG)
RELAY-1 (136.140) with IMP-4 (136.140) at 24/1426Z to 1520Z	RELAY-1 with IMP-4 at 24/1451Z to 1510Z (SANTIAGO)
IQSY-1 (136.530) with ERS-18 (136.530) at 24/0922Z to 0930Z	IQSY-1 with ERS-18 at 24/0922Z to 0932Z (JOBURG)
RELAY-1 (136.140) with IMP-4 (136.140) at 24/0506Z to 0608Z	RELAY-1 with IMP-4 at 24/0520Z to 0530Z (MADGAR)
RELAY-1 (136.140) with IMP-4 (136.140) at 24/0830Z to 0842Z	RELAY-1 with IMP-4 at 24/0830Z to 0837Z (MADGAR)
RELAY-1 (136.140) with IMP-4 (136.140) at 24/2040Z to 2116Z	RELAY-1 with IMP-4 at 24/2040Z to 2045Z (ORRORAL)
FR-1A (136.800) with ESSA-2 (136.769) at 25/0310Z to 0316Z	RFI with ESSA-2 at 25/0310Z to 0314Z (MADGAR)
ALOU-1 (136.592) with UK-3 (136.560) at 25/0852Z to 0856Z	Satellite RFI with UK-3 at 25/0855Z (JOBURG)
RELAY-1 (136.140) with IMP-4 (136.140) at 25/1134Z to 1248Z	RELAY-1 with IMP-4 at 25/1153Z to 1239Z (SANTIAGO)
IQSY-1 (136.530) with ERS-18 (136.530) at 25/2356Z	IQSY-1 with ERS-18 at 25/2354Z to 26/0004Z (ORRORAL)
IQSY-1 (136.530) with ERS-18 (136.530) at 25/2212Z to 2218Z	IQSY-1 with ERS-18 at 25/2211Z to 2219Z (ORRORAL)
IQSY-1 (136.530) with ERS-18 (136.530) at 25/1918Z to 1926Z	IQSY-1 with ERS-18 at 25/1917Z to 25/1923Z (ROSMAN)
RELAY-1 (136.140) with IMP-4 (136.140) at 25/0554Z to 0650Z	RELAY-1 with IMP-4 at 25/0610Z to 0641Z (MADGAR)
ATS-2 (136.470) with ERS-18 (136.530) at 25/0850Z to 0914Z	Satellite RFI with ERS-18 at 25/0852Z to 0857Z (SANTIAGO)

The space above the earth is becoming saturated with 136 MHz emissions as revealed from a prediction of the number of multiple satellites, interfering simultaneously, over a typical STADAN station. Twenty-nine (29) near-earth satellites were considered using the MADGAR (Tananarive, Malagasy Republic) Minitrack site. The RFI prediction printout listing for MADGAR revealed a total of 103 potential RFI events, involving two (2) or more satellites, for the twenty-four (24) hour period on March 29, 1967

There was one unusual RFI event predicted for the MADGAR Minitrack station involving four (4) satellites, simultaneously (see Table 2). If the MADGAR site had been tracking the BE-B satellite on 136.171 MHz, four (4) minutes of continuous interference from three (3) other satellites could have existed from 29/0000Z to 29/0004Z.

Table 2
Predicted RFI Events Involving Four (4) Satellites for Madgar Minitrack
Tracking BE-B Satellite.

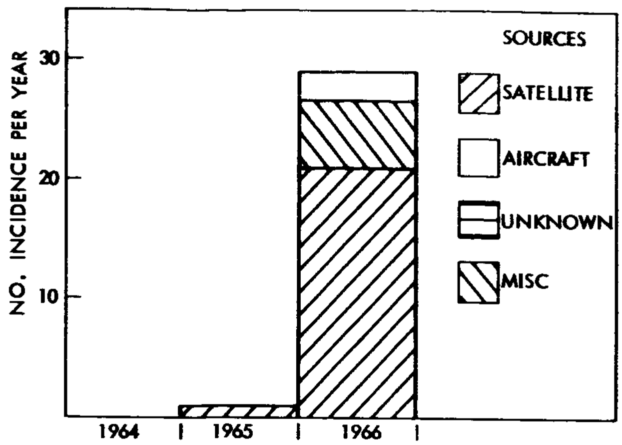
RFI Event Time (HH MMSS)	Station: Madgar Type: Minitrack Date: March 29, 1967
	Satellites Involved in Single RFI Event
29/000000Z to 000400Z (4 minutes)	OGO-1 (136.201 MHz ± 15 KHz) with BE-B (136.171 MHz ± 30 KHz)
	OGO-3 (136.200 MHz ± 15 KHz) with BE-B (136.171 MHz ± 30 KHz)
	IMP-3 (136.124 MHz ± 20 KHz) with BE-B (136.171 MHz ± 30 KHz)

STADAN-STATION YEARLY RFI REPORT SUMMARIES

Yearly summaries of STADAN-station RFI reports, for the past three (3) years, indicate a high percentage of the reported interference was due to RFI from satellites (see Figures 11, 12 and 13). For example, the Table 3 summary shows that from 58% to 94% of the reported RFI events were caused by satellites for the three (3) stations considered.

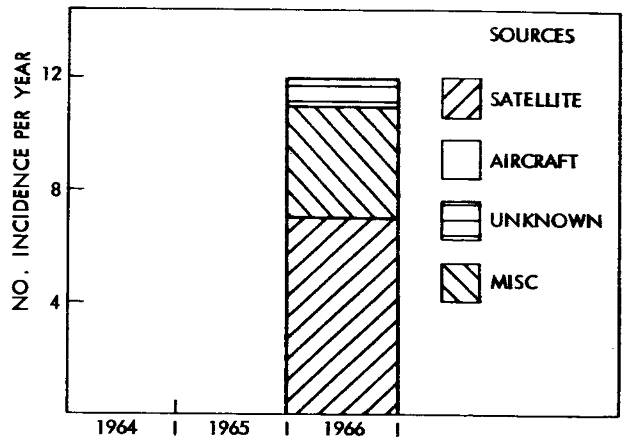
The average time duration of the station-reported RFI events in 1966 ranges from 0.41 minutes per event for the Lima, Peru, station to 11.9 minutes per event for the Fort Myers, Florida, station.

A word should be said at this point about the total number of reported satellite RFI events, in the yearly summaries, that range from seven (7) to 115 interference events per station, in 1966, for the three (3) stations considered. The computer-predicted interference for the MADGAR



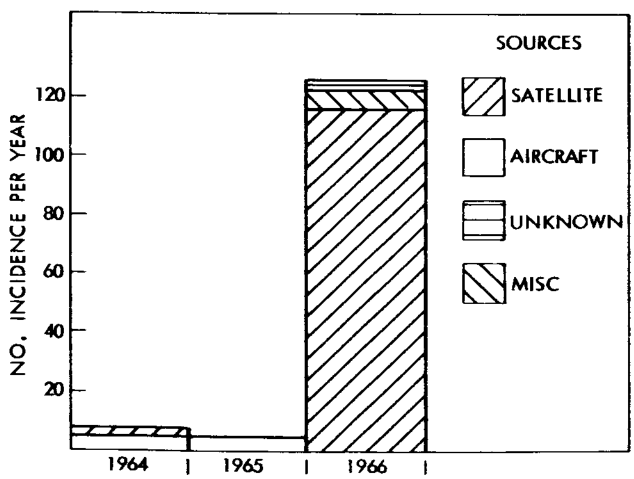
YEAR	AVERAGE DURATION OF INTERFERENCE (minutes)
1964	
1965	23.1
1966	11.9
TOTAL AVERAGE	12.27

Figure 11—Yearly RFI report summary (Ft. Myers, Florida station).



YEAR	AVERAGE DURATION OF INTERFERENCE (minutes)
1964	
1965	
1966	0.41
TOTAL AVERAGE	0.41

Figure 13—Yearly RFI report summary (Lima, Peru station).



YEAR	AVERAGE DURATION OF INTERFERENCE (minutes)
1964	6.25
1965	3.4
1966	7.08
TOTAL AVERAGE	6.59

Figure 12—Yearly RFI report summary (College, Alaska station).

Table 3

Summary of STADAN-Station RFI Events for 1966.

STADAN Station	Total No. RFI Events	No. Satellite RFI Events	Percentage RFI Events Due to Satellites
Fort Myers, Florida	29	21	72%
College, Alaska	122	115	94%
Lima, Peru	12	7	58%

Minitrack station, for example, indicates a much larger number of RFI events (i.e., total of 103 events per twenty-four (24) hours). There are several reasons for the apparent difference; namely:

(1) For analytical reasons, the computer-prediction program assumes that all 136 MHz satellite transmitters are continuously radiating.

(2) Satellite "on-off" command schedules reduce the satellite transmitter "on" time.

(3) STADAN stations do not track or take data on all satellite passes.

The number of STADAN-station radio frequency interference reports have substantially increased in 1967 compared to 1966. For example, during the month of May 1967, 358 separate interference reports were filed by the network stations. The largest portion, 271, was identified or suspected as being caused by multiple satellites, radiating in the 136-138 MHz band, simultaneously visible over the same site. This figure is much larger than the value of only 68 satellite interference reports, from all stations, for the month of December, 1966. The remaining 87 interference events for May 1967 were identified as being caused by solar flare activity, aircraft, or from unknown sources.

CONCLUSIONS

A computer-controlled prediction program has been developed for the STADAN network to reduce radio frequency interference between multiple satellites by means of appropriate station operations re-scheduling. This program, written in Fortran IV format for the UNIVAC 1108 operational computer, will handle up to 50 satellites and 50 ground stations. Forty (40) satellites, including certain non-supported satellites, have been included in the program to date.

A new RFI prediction program is currently being written, in FORTRAN G and H format for the IBM 360/75 computer, that will handle up to 100 satellites; accept Brouwer Mean and NORAD type orbital elements with equal accuracy; and have as an input the satellite command schedule.

The existing program is flexible in that predictions can be made for certain selected stations and satellites. For example, predictions for the 10 Minitrack stations may be run as a separate program; and interference conflict predictions, for as few as 2 satellites, can be made for a given 24 hour period. Furthermore, program parameters, including the threshold signal-to-interference ratio and satellite transmit spectral bandwidth, can be readily adjusted to meet various mission requirements.

The accuracy of the program has been verified by comparing RFI predictions with STADAN-station reported satellite interference, and good agreement has been obtained. In addition, this program can be utilized to generate satellite orbit predictions for the STADAN stations. For example, generated orbit prediction printouts were compared with conventional operations-type predictions for the GEOS-A, IQSY, ESSA-3, and Relay-2 satellites. Good agreement was obtained wherein the antenna x-y axis pointing angles correlated within one-half degree (0.5°) for the two methods.

The highly-elliptical orbit satellites, such as AIMP-D, are not included in the existing computer prediction program. However, a number of the satellites reported through the North American Air Defense Command (NORAD) have already been integrated into the program. These include NORAD satellites, UK-2, EGRS-6, EGRS-8, SYNCOM-2 and SYNCOM-3.

This prediction program should be effective in reducing the steadily increasing number of STADAN RFI events involving multiple satellites. For example, in May 1967, there were about 270 reported satellite RFI events compared to only 68 satellite RFI events in December 1966. The May 1967 data indicates that serious RFI from satellites exists in about 2% of all passes, and is steadily increasing as more satellites go into orbit.

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