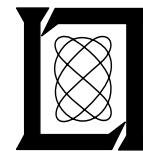# ATCRBS Uplink Environment Measurements Near Jacksonville, Florida

F. Nagy, Jr.

25 September 1981

## Lincoln Laboratory

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

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**16. Abstract**

Airborne measurements of the Air Traffic Control Radar Beacon System (ATCRBS) 1030 MHz uplink environment are described. Measurements were made using the AMF, a special purpose airborne sensor-recorder, during a 23 May 1979 flight in the greater Jacksonville, Florida area. The 2-way flight covered the 450 nm coastline between Fayetteville (NC) and Vero Beach (FL) first at 10,000 then at 25,000 feet.

Data recorded at 61 locations have been analyzed to plot combined pulse, interrogation and suppression rates for all locations and individual rates, received powers and angles for 37 locations. Fifty-nine ground interrogators were detected and a list included serves as an all-interrogator/all location (59 × 37) visibility matrix. PRI/PRF distributions of interrogations received are shown at three selected measurement locations. A pulse-by-pulse plot of over 50 Mode 4 interrogations shows their effect on a typical transponder.

A "worst" location is examined for peak instantaneous interrogation rates capable of causing transponder reply-rate limiting (RRL), desensitization and track loss. Durations and periods of recurrence of "synchronous jamming" for 23 near-equal scan periods are computed. Probabilities of multiple mainbeam coincidences ("multi-PRF jamming") are also calculated. Airborne (AMF) and ground based (FAA En-Route) coverages are compared, and reported operational problems (target splits, lost tracks, poor coverage) are addressed.

| 17. Key Words ATCRBS Uplink Environment Beacon Interrogators Interrogations/Suppressions Reflections Synchronous Jamming Mode 4 | 18. Distribution Statement Document is available to the public through the National Technical Information Service, Springfield, Virginia 22151 | | |
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| **19. Security Classif. (of this report)** Unclassified | **20. Security Classif. (of this page)** Unclassified | **21. No. of Pages** 126 | **22. Price** |

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# CONTENTS (cont.)

FIGURES

## ORGANIZATION OF REPORT

Section 1 serves as an introduction. It describes the purpose of the uplink measurements in the Jacksonville area; it outlines the functions of the AMF and of the uplink analysis program in the recording and processing of the measurements; it shows the two legs of the flight path, the places where measurements were made, and major interrogators of the area.

Section 2 gives combined results on the Jacksonville area uplink environment in which individual interrogators are not yet separated. Total pulse, suppression and interrogation counts are tabulated and plotted for all measurement locations. The number of interrogators seen is given at 38 of the 61 measurement locations.

Section 3 enumerates the basic parameters (PRI, PRF, mode interlace, scan period, stagger length) of the 59 interrogators observed during the flight. It also gives an all-location/all-interrogator visibility matrix, and a master list of local individual interrogator results. This includes interrogations per minute, angle-of-arrival, average and peak power, PRI/PRF distributions, and a (partial) list of reflections and Mode 4 interrogations. A pulse-by-pulse plot of over 50 Mode 4 interrogations is presented. These pulses are applied to a model of a nominal transponder to determine their effect on the civil beacon environment. Some observations of high instantaneous interrogation and suppression rates are considered next; these are investigated from the point of view of reply rate limiting (RRL) and percentage un-availability of a transponder.

Section 4 treats the "busiest" measurement location seen (loc. 2M+, 24nm east of Whitehouse ARSR, at 25,000 ft) where 31 interrogators were observed. First an average "effective" beamwidth (which includes all sidelobe interrogations) is calculated (to be used subsequently for the multiple-interrogation probability calculations of Appendix A). A set of figures showing (high) instantaneous interrogations around two consecutive mainbeams of five en-route interrogators of the Jacksonville Center is examined from the point of view of reply rate limiting and possible track loss. Finally, a plot of over 3000 mainbeam passages, extrapolated from the 31 scan periods measured at loc. 2M+, is presented. Duration, and repetition frequency of the Jedburg/Patrick and Patrick/Whitehouse mainbeam coincidences are calculated. Synchronous jamming at 2M+ is treated in Appendix B.

Section 5 compares AMF "coverage" (visibility) with ground interrogator coverage based on simultaneous FAA recordings at the Jacksonville Center. It shows the two (ground based and airborne) coverages to be in almost 100 percent agreement. It also shows that missing target reports correlate uniquely with marginal uplink (and downlink) propagation.

Section 6 contains a detailed summary of results, including those given in the Appendices.

Section 7 draws some conclusions from the results of the flight. It compares the results with earlier uplink measurements and addresses some of the operational problems (target splits, lost tracks, poor coverage, etc.) noted at Jacksonville Center.

Using the Binomial Distribution as a model, and the average "effective" beamwidth of Sec. 4 as a parameter, Appendix A calculates the likelihood of multiple interrogations at loc. 2M+ (note that the underlying phenomenon is also called "multi-PRF jamming" and "multiple mainbeam coincidence" throughout this report). The effect of possibly un-detected military interrogators without SLS is emphasized.

Appendix B treats synchronous jamming at location 2M+. A figure showing incremental scan periods for 23 interrogators divided between the three most popular scan periods (3.92, 4.70 and 12.01 sec) is presented first. Synchronous jamming is defined, and its minimum and maximum durations and periods of recurrence (based on maximum and minimum scan differences in each of the three groups) are calculated. Two expressions are given for higher order jamming probabilities, with an explanation of their relationship. Some 16 "general" and "special" probability curves (or portions thereof) are presented next. These curves allow the reader to estimate higher order mainbeam coincidence probabilities as a function of the number of interrogators present.

Appendix C provides definitions of the terms interrogations, suppressions, and stray pulses used in the report.

Note: The information contained in this report was derived from airborne measurements made in the Jacksonville, FL, area and therefore much of it is peculiar to that area. However, many of the results are valid for a more general uplink environment. Typical of the latter type of information are:

- The effect of Mode 4 interrogations on typical airborne transponders (Figures 9a-9d).

- The likelihood of multiple mainbeam coincidences as presented in Appendix B (especially in Figure B-2).

- The duration and time of recurrence of mainbeam overlaps on near-equal scan periods (shown in Figure B-1).

- The relationship between deadtime, PRI difference and number of consecutive missing replies (presented in Sec. 7.2.5).

## 1.0  INTRODUCTION

### 1.1 Purpose of Measurements

In-flight measurements[*] of the Air Traffic Control Radar Beacon System (ATCRBS) uplink environment on 1030 MHz were made for the FAA Airways Facilities Service on 23 May 1979 using the MIT Lincoln Laboratory Airborne Measurements Facility (AMF).[**] These measurements were made for the purpose of:

- Characterizing the pulse, interrogation and suppression environment in the the larger Jacksonville, Fla. area.

- Identifying and characterizing the ground interrogators contributing to the measured airborne environment in the larger Jacksonville area.

- Finding possible causes of target splits, lost tracks and coverage anomalies, especially at the boundaries of the Jacksonville Air Route Traffic Control Center (ARTCC).

- Measuring interrogation "bunching", the degree of reply rate limiting (RRL) and transponder desensitization.

- Measuring suppression bunching and the corresponding transponder unavailability.

- Comparing AMF "coverage" (visibility) with coverage from simultaneous FAA recordings at the Jacksonville Center.

- Showing reflections.

- Showing details of mode 4 interrogations, and their effect on an "average" airborne transponder.

- Describing the worst cases encountered of "synchronous" and "random jamming" (multiple mainbeam and/or sidelobe coincidences with multi-PRF interrogations).

- Permitting the calculation of the probability of occurrence for various degrees of multi-PRF jamming.

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*Similar measurements for other areas are reported in (1) "Uplink Coverage Measurements in the Los Angeles Area for Passive BCAS", F. Nagy, Jr., Project Report ATC-81, Lincoln Laboratory, M.I.T. (7 November 1977), FAA-RD-77-134, and (2) "Uplink ATCRBS Environment Measurements Along the Boston-Washington Corridor", F. Nagy, Jr., Project Report ATC-83, Volumes 1 and 2, Lincoln Laboratory, M.I.T. (27 June 1978 and 28 February 1979), FAA-RD-78-33.

**See "The Airborne Measurements Facility (AMF) System Description", G. V. Colby, Project Report ATC-60, Lincoln Laboratory, M.I.T. (25 March 1976), FAA-RD-75-233.

1

These measurements have provided data which will contribute to the understanding and resolution of existing ATCRBS interference and ATCRBS interrogator site coverage problems. They also serve to define the radiation environment in which beacon-related systems such as BCAS and DABS must operate in the future.

## 1.2 Recording and Processing of Measurement Data

The beacon uplink environment consists of interrogation pulses (P1 and P3) and sidelobe or suppression pulses (P2) originating from FAA and military interrogators. In addition, pulse energy is transmitted from TACAN equipment operating in or near the 1030 MHz band. The AMF records the level, time of arrival and duration of each of those pulses whose amplitide exceeds a preselected threshold (generally -75 dBm at the bottom-mounted antenna of the AMF) for at least 375 nsec, provided its leading edge rises at least 6 dB in an interval of 125 nsec. An estimate of the relative bearing of the source of each pulse is also recorded. The pulse amplitude information is digitized with 1 dB resolution and recorded, together with aircraft position and time-of-day, for later analysis.

An AMF uplink analysis program, resident in a ground-based computer, then a) associates the valid pulses of ATCRBS interrogation modes and suppression pairs; b) provides amplitude distributions and total event counts for each mode; c) arranges the interrogations in a time-ordered interrogation file; d) calculates all interrogation repetition intervals (PRI's) present in the interrogation data; and e) segregates and associates all interrogations from a given interrogator, thereby permitting identification of interrogator dwell time, beamwidth and scan period. The mode interlace pattern of the interrogator is also determined, and deviations of the actual time of occurrence of the interrogations from the expected time are calculated.

The aircraft in which the AMF was installed was a twin-engine Cessna 421. The Cessna's own transponder and DME were used during the flight, along with the AMF's DME equipment. To prevent their transmissions on 1090 MHz from leaking into the uplink recordings on 1030 MHz, a digital blanking circuit was installed at the AMF input.

The interrogation and suppression rate data presented in this report have been obtained from the output of the uplink analysis program. This program does not simulate either the 35 µs (ave) suppression experienced by a real transponder, or the 60 µs (ave) deadtime following a Mode A or C reply. Thus the AMF measures slightly higher interrogation and suppression rates than an ATCRBS transponder on board would see. The discrepancy is less than 5 percent even at location (1V) where the highest suppression rate was observed.

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## 1.3 Jacksonville Flight Path (Figure 1)

Figure 1 shows the complete flightpath, all measurement locations along it, and all interrogators in the area (from the 26 January 1979 ECAC interrogator file). FAA interrogators are shown by solid circles, military interrogators by broken circles. Double circles (for either category) indicate en-route interrogators.

Wilmington (NC) and Vero Beach (Fla) were the end-points of the flight. The AMF flew south along the coast at 10,000 ft, and then returned to Wilmington flying north over the ocean at 25,000 ft. The southerly leg included part of a 50-nm circle around the Jacksonville VORTAC (JAX), while the northerly leg included a two-way 95 degree radial flight from location H (2H, see below) to JAX and back.

Automatic (1 minute out of 10) recording locations are noted by consecutive letters of the alphabet (A, B, C, etc.). Manual recording locations approximately half-way in-between are noted by a "+" sign (e.g. A+, B+, etc.). Measurement locations along the southerly leg of the flight are preceded by the number "1" (e.g. 1A, 1B, etc.), while measurement locations on the northerly leg of the flight are preceded by the number "2" (e.g. 2A, 2B, etc.).

Latitudes and longitudes are shown in equal increments in Fig. 1. North-south distances are true: each degree corresponds to exactly 60 nmi. East-west distances are exaggerated: 10, 13, and 17 percent, respectively, at the latitudes of Miami, Jacksonville and Wilmington, respectively.

### 1.3.1 Geographical Symmetry of the Flight

As can be seen from the map the higher altitude (25,000 ft) return flight of the AMF deviated from the lower altitude (10,000 ft) inland flight, by an offset that varied from about 50 to 150 nmi. Exceptions to this occured only during the 50-nmi DME circle around JAX (Jacksonville VORTAC) (locations 1L to 1Q), and during the 150 nmi two-way radial against JAX (locations 2I to 2R).

Some interrogators observed by the AMF at the beginning, middle and end of its southerly flight were observed again at corresponding portions of its return flight, resulting in some degree of mirror symmetry in visibility about the landing at Vero Beach (locations 1X and 2A).

### 1.3.2 Distance to Horizon (Nominal)

Nominal visibility for the first leg of the flight (at 10,000 ft) was 125 nmi. This increased to 190 nmi for the second leg (at 25,000 ft). This plus transmitted power are the major factors determining the "run lengths" (extents of visibility) for the terminal and enroute interrogators seen during the flight.

3

DATA RECORDING LOCATIONS FOR 23 MAY 1979
JACKSONVILLE AREA FLIGHT OF THE AMF

FIGURE 1

4

## 2.0 OVERALL PULSE ENVIRONMENT FOR ALL INTERROGATORS

Tables 1 and 2 with Figs 2-5 present the overall pulse environment as observed at each measurement location along the flight path. The tables list the lat-long coordinates, start time and duration, total interrogation/suppression counts, and pulse rates (averaged over the observation interval) for each measurement location. They also list the number of interrogators seen for 38 selected locations.

### 2.1 Total Pulse Rate

Total pulse rates run just under 3000 PPS for the southerly leg of the flight (Fig. 2), with only one large peak of 9000 PPS at loc. 1R+[*], about 2 nmi south-east of Craig Municipal Airport in Jacksonville, Fla. A smaller peak of 4000 PPS occurs near Cape Canaveral (loc. 1V).

Pulse rates over the ocean are much lower and are much less uniform (Fig. 4). Only at the nearest points of the JAX radial flight is the rate of 5000 PPS exceeded. A smaller peak of 2000 PPS is observed near Wilmington.

Unassociated (stray) pulses typically make up one-to two-thirds of the total on both legs of the flight. These are probably made up of P2 pulses from military interrogators without improved SLS (ISLS), TACAN pulses, and multipath reflections of all actual pulses.

### 2.2 Suppression Rates

Suppression rates are typically the least uniform of any of the rates measured by the AMF. The reason for this is that the P2 pulses are transmitted not on the directional antennas of the interrogators, but rather on their omni antennas, with their attendant lower gains and shorter operating ranges.

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[*]At location 1R+ the AMF came within 5 nmi of a powerful television transmitter (WJKS-TV, Ch. 17, 100 KW, visual frequency 500.00 MHz), and probably recorded some of its double-frequency transients. An AMF pulse data dump shows that about half of the data recorded in that area consists of pulses separated, alternately, by 272.25 and 288.25 µs (ave. PRI = 280.25 µs, ave. PRF = 3568.45). Half of these are single pulses, the other half pulse pairs 1 µs apart (widths: 0.5 and 0.375 µs, respectively).

## TABLE 1

### 23 May, 1979 Jacksonville Flight of the AMF
### Southerly (Overland) Portion at 10,000 Ft.
### (Locations 1A, 1B, Etc).

| LATITUDE | LONGITUDE | LOCATION CODE | OBSERVATION TIME START | | | DURATION (SEC) | TOTAL PULSES | PER SECOND RATES SUPPRESSIONS | | INTERROGATIONS | | | | STRAY PULSES | NO. OF INTERROGATORS SEEN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | HR | MIN | SC | | | 2-PLS | 3-PLS | MDA | MDC | MD1 | MD2 | | |
| 34 00 | 78 26 | 1A | 7 | 59 | 01 | 58 | 2287 | 300 | 11 | 149 | 79 | 2 | 61 | 1042 | 15 |
| 33 43 | 78 50 | 1B | 8 | 09 | 01 | 58 | 2672 | 166 | 219 | 156 | 79 | 8 | 60 | 1032 | 12 |
| 33 25 | 79 11 | 1C | 8 | 19 | 01 | 58 | 2140 | 35 | 31 | 140 | 71 | 4 | 62 | 1387 | 13 |
| 33 13 | 79 39 | 1D | 8 | 29 | 01 | 58 | 2655 | 537 | 53 | 79 | 42 | 7 | 31 | 1075 | 14 |
| 32 55 | 80 01 | 1E | 8 | 39 | 01 | 58 | 3062 | 344 | 375 | 62 | 30 | 29 | 22 | 896 | 13 |
| 32 36 | 80 20 | 1F | 8 | 49 | 01 | 58 | 2589 | 510 | 70 | 47 | 31 | 36 | 25 | 1036 | 16 |
| 32 15 | 80 34 | 1G | 8 | 59 | 01 | 58 | 2932 | 609 | 34 | 73 | 57 | 65 | 51 | 1073 | 14 |
| 31 58 | 80 58 | 1H | 9 | 09 | 01 | 58 | 2236 | 445 | 14 | 55 | 36 | 68 | 29 | 887 | 19 |
| 31 33 | 81 09 | 1I | 9 | 19 | 01 | 58 | 1693 | 190 | 16 | 36 | 25 | 25 | 24 | 1019 | 18 |
| 31 10 | 81 24 | 1J | 9 | 29 | 01 | 58 | 2101 | 163 | 121 | 33 | 22 | 14 | 19 | 1183 | 15 |
| 30 46 | 81 30 | 1K | 9 | 39 | 01 | 58 | 2720 | 347 | 163 | 36 | 24 | 13 | 18 | 1310 | 14 |
| 30 27 | 81 42 | 1L | 9 | 49 | 24 | 36 | 3770 | 317 | 590 | 45 | 28 | 14 | 22 | 1088 | 10 |
| 30 29 | 82 14 | 1M | 9 | 59 | 01 | 58 | 2405 | 209 | 156 | 34 | 24 | 11 | 15 | 1313 | 10 |
| 30 43 | 82 29 | 1N | 10 | 09 | 01 | 58 | 3188 | 322 | 48 | 31 | 19 | 18 | 17 | 2184 | 10 |
| 31 06 | 82 11 | 1N+ | 10 | 17 | 02 | 58 | 2922 | 188 | 107 | 36 | 24 | 20 | 20 | 1952 | |
| 31 11 | 82 02 | 10 | 10 | 19 | 23 | 98 | 2698 | 226 | 105 | 37 | 25 | 25 | 19 | 1639 | 14 |
| 31 17 | 81 30 | 1P | 10 | 29 | 01 | 58 | 1718 | 24 | 37 | 38 | 26 | 17 | 20 | 1316 | 15 |
| 30 56 | 81 30 | 1Q | 10 | 39 | 01 | 58 | 2325 | 261 | 94 | 38 | 25 | 21 | 20 | 1253 | 14 |
| 30 31 | 81 32 | 1R | 10 | 49 | 01 | 58 | 3783 | 327 | 260 | 32 | 0 | 17 | 19 | 2124 | 8 |
| 30 26 | 81 33 | 1R | 10 | 50 | 30 | 90 | 4516 | 317 | 381 | 40 | 24 | 17 | 19 | 2487 | |
| 30 19 | 81 29 | 1R+ | 10 | 54 | 10 | 48 | 9082 | 391 | 352 | 59 | 41 | 33 | 35 | 6829 | |
| 30 08 | 81 23 | 1S | 10 | 59 | 01 | 58 | 3727 | 260 | 319 | 48 | 29 | 28 | 25 | 1922 | 12 |
| 29 43 | 81 14 | 1T | 11 | 09 | 01 | 58 | 2509 | 124 | 133 | 48 | 31 | 22 | 21 | 1559 | 13 |
| 29 17 | 81 03 | 1U | 11 | 19 | 01 | 58 | 3006 | 626 | 92 | 55 | 30 | 26 | 24 | 1154 | 18 |
| 29 05 | 81 03 | 1U+ | 11 | 23 | 20 | 59 | 3164 | 624 | 172 | 51 | 30 | 26 | 22 | 1089 | |
| 28 50 | 80 57 | 1V | 11 | 29 | 01 | 58 | 4101 | 1195 | 107 | 42 | 25 | 31 | 24 | 1083 | 15 |
| 28 33 | 80 49 | 1V+ | 11 | 35 | 50 | 43 | 4116 | 932 | 118 | 47 | 30 | 25 | 30 | 1546 | |
| 28 26 | 80 45 | 1W | 11 | 39 | 01 | 58 | 3573 | 882 | 212 | 40 | 24 | 28 | 23 | 868 | 17 |
| 28 09 | 80 39 | 1W+ | 11 | 45 | 11 | 51 | 3105 | 558 | 412 | 31 | 15 | 20 | 14 | 527 | |
| 27 56 | 80 35 | 1X | 11 | 49 | 01 | 58 | 1948 | 516 | 85 | 15 | 7 | 15 | 10 | 538 | 4* |

*AMF aircraft at low altitude

TABLE 2

23 May 1979 Jacksonville Flight of the AMF
Northerly Portion at 25,000 Ft. (Over the Ocean)
(Location 2A, 2B, Etc.)

| LATI-TUDE | LONGI-TUDE | LOCA-TION CODE | OBSERVATION TIME | | | | PER SECOND RATES | | | | | | | STRAY PLSES | NO. OF INTER-ROGATORS SEEN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | START | | | DURA-TION | TOTAL | SUPPRESSIONS | | INTERROGATIONS | | | | | |
| | | | HR | MIN | SC | (SEC) | PULSES | 2-PLS | 3-PLS | MD A | MD C | MD 1 | MD 2 | | |
| 27 44 | 79 58 | 2A | 13 | 19 | 01 | 58 | 894 | 321 | 36 | 11 | 8 | 5 | 3 | 76 | 5* |
| 27 55 | 79 36 | 2B | 13 | 29 | 01 | 58 | 783 | 286 | 10 | 15 | 9 | 1 | 2 | 108 | |
| 28 21 | 79 24 | 2C | 13 | 39 | 01 | 58 | 655 | 182 | 2 | 16 | 9 | 2 | 4 | 196 | 9 |
| 28 48 | 79 18 | 2D | 13 | 49 | 01 | 58 | 1050 | 177 | 6 | 23 | 14 | 3 | 8 | 554 | |
| 29 10 | 79 05 | 2E | 13 | 59 | 01 | 58 | 1352 | 101 | 10 | 27 | 18 | 5 | 11 | 955 | 12 |
| 29 20 | 78 45 | 2F | 14 | 09 | 01 | 58 | 273 | 9 | 1 | 24 | 16 | 7 | 10 | 130 | |
| 29 55 | 78 54 | 2G | 14 | 19 | 01 | 58 | 525 | 55 | 0 | 21 | 15 | 6 | 11 | 286 | 9 |
| 30 27 | 78 57 | 2H | 14 | 29 | 01 | 58 | 899 | 61 | 9 | 27 | 17 | 7 | 11 | 594 | |
| 30 31 | 79 12 | 2I | 14 | 39 | 01 | 58 | 1007 | 30 | 40 | 31 | 22 | 12 | 14 | 637 | 15 |
| 30 35 | 79 42 | 2J | 14 | 49 | 01 | 41 | 1823 | 71 | 169 | 34 | 22 | 9 | 14 | 974 | |
| 30 31 | 80 00 | 2J+ | 14 | 54 | 50 | 70 | 3356 | 92 | 246 | 53 | 37 | 19 | 29 | 2084 | |
| 30 30 | 80 12 | 2K | 14 | 59 | 01 | 58 | 2610 | 138 | 316 | 40 | 26 | 7 | 17 | 1158 | 17 |
| 30 27 | 80 30 | 2K+ | 15 | 5 | 0 | 60 | 3836 | 165 | 274 | 56 | 35 | 17 | 23 | 2367 | |
| 30 27 | 80 42 | 2L | 15 | 09 | 01 | 58 | 2643 | 228 | 194 | 49 | 31 | 13 | 20 | 1321 | |
| 30 27 | 81 03 | 2L+ | 15 | 15 | 42 | 50 | 5305 | 345 | 143 | 66 | 45 | 24 | 27 | 801 | |
| 30 28 | 81 13 | 2M | 15 | 19 | 01 | 58 | 3627 | 467 | 174 | 73 | 41 | 21 | 20 | 1782 | 27 |
| 30 27 | 81 26 | 2M+ | 15 | 24 | 0 | 60 | 4289 | 624 | 227 | 68 | 47 | 20 | 103 | 1811 | 31 |
| 30 29 | 81 08 | 2N+ | 15 | 34 | 47 | 67 | 4087 | 359 | 156 | 69 | 45 | 21 | 23 | 2512 | |
| 30 29 | 80 50 | 2O | 15 | 39 | 02 | 57 | 2730 | 235 | 155 | 57 | 37 | 17 | 21 | 1470 | 26 |
| 30 33 | 80 13 | 2P | 15 | 49 | 03 | 57 | 2833 | 236 | 301 | 54 | 38 | 14 | 28 | 1108 | |
| 30 34 | 79 35 | 2Q | 15 | 59 | 03 | 56 | 1370 | 17 | 58 | 39 | 23 | 16 | 19 | 927 | 18 |
| 30 34 | 78 56 | 2R | 16 | 09 | 08 | 52 | 917 | 6 | 15 | 35 | 22 | 14 | 17 | 663 | |
| 31 02 | 78 42 | 2S | 16 | 19 | 7 | 53 | 1012 | 4 | 15 | 42 | 27 | 23 | 26 | 690 | 15 |
| 31 39 | 78 19 | 2T | 16 | 29 | 06 | 54 | 914 | 4 | 13 | 34 | 24 | 15 | 23 | 652 | |
| 32 13 | 78 11 | 2U | 16 | 39 | 05 | 55 | 465 | 3 | 5 | 48 | 17 | 11 | 14 | 248 | 20 |
| 32 40 | 78 14 | 2V | 16 | 49 | 01 | 58 | 1036 | 5 | 9 | 66 | 22 | 19 | 17 | 731 | |
| 33 17 | 78 10 | 2W | 16 | 59 | 04 | 56 | 1586 | 44 | 22 | 71 | 26 | 16 | 16 | 1143 | 20 |
| 33 50 | 77 57 | 2X | 17 | 09 | 01 | 58 | 1909 | 363 | 137 | 71 | 26 | 7 | 10 | 518 | |
| 34 09 | 78 07 | 2X+ | 17 | 14 | 02 | 59 | 2100 | 393 | 159 | 48 | 24 | 11 | 10 | 621 | |
| 34 26 | 78 23 | 2Y | 17 | 19 | 01 | 58 | 2070 | 361 | 42 | 38 | 20 | 2 | 3 | 1061 | 13 |
| 34 41 | 78 36 | 2Y+ | 17 | 24 | 20 | 49 | 1246 | 91 | 15 | 32 | 17 | 2 | 1 | 882 | |

*AMF aircraft at low altitude
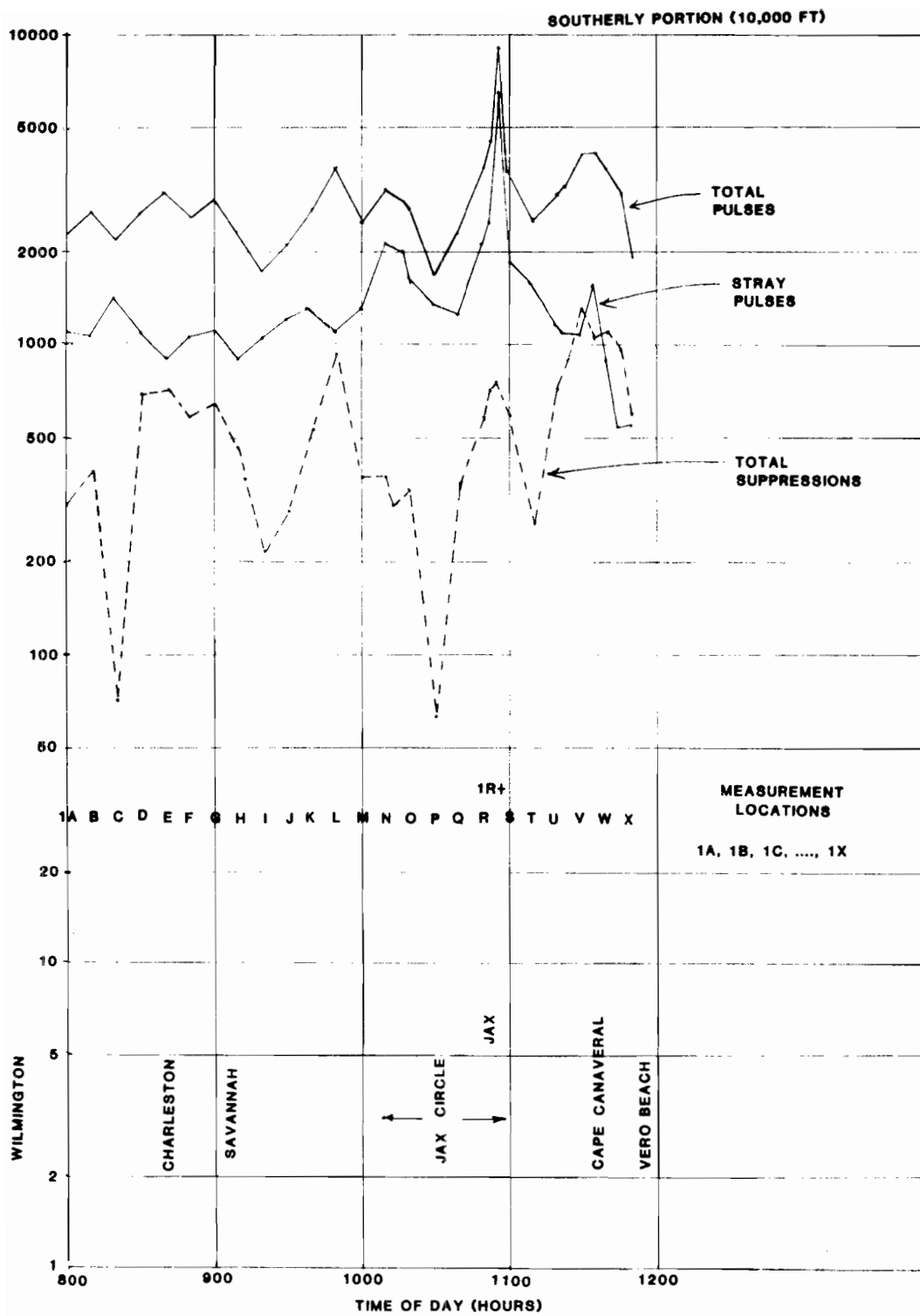
Combined Pulse And Suppression Rates Overland
Figure 2
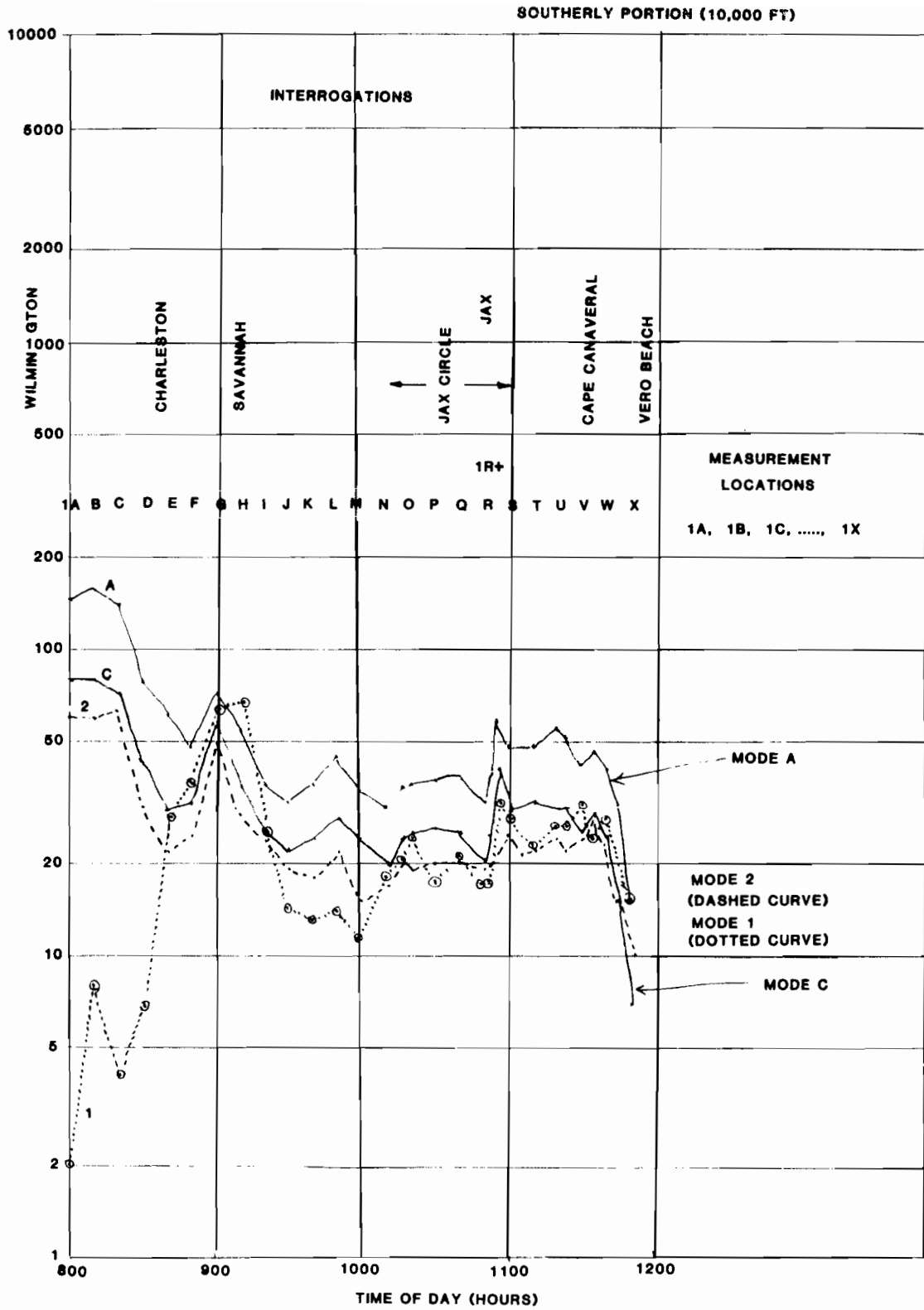
Combined Interrogation Rates Overland
Figure 3

9
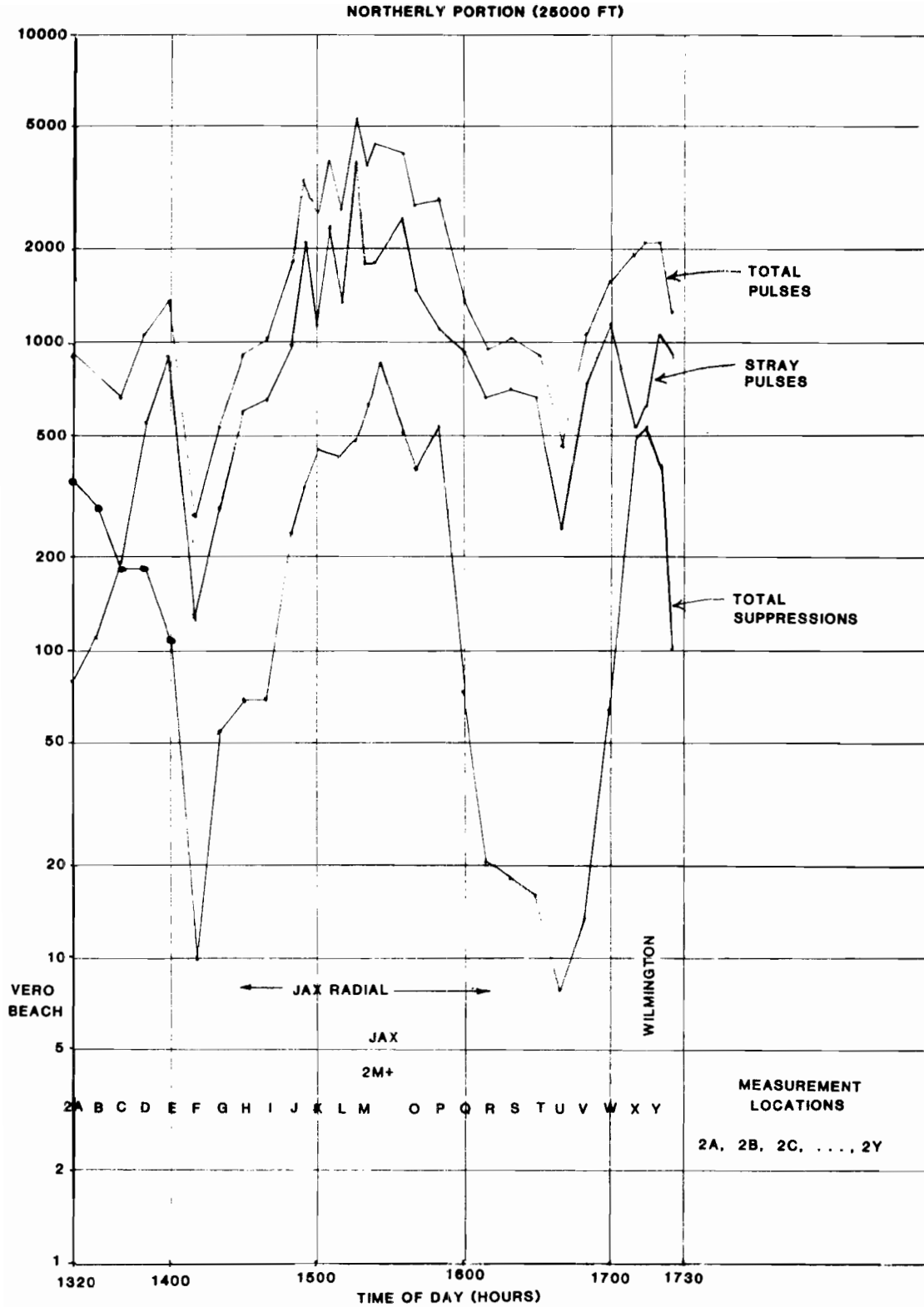
Combined Pulse And Suppression Rates over the Ocean
Figure 4
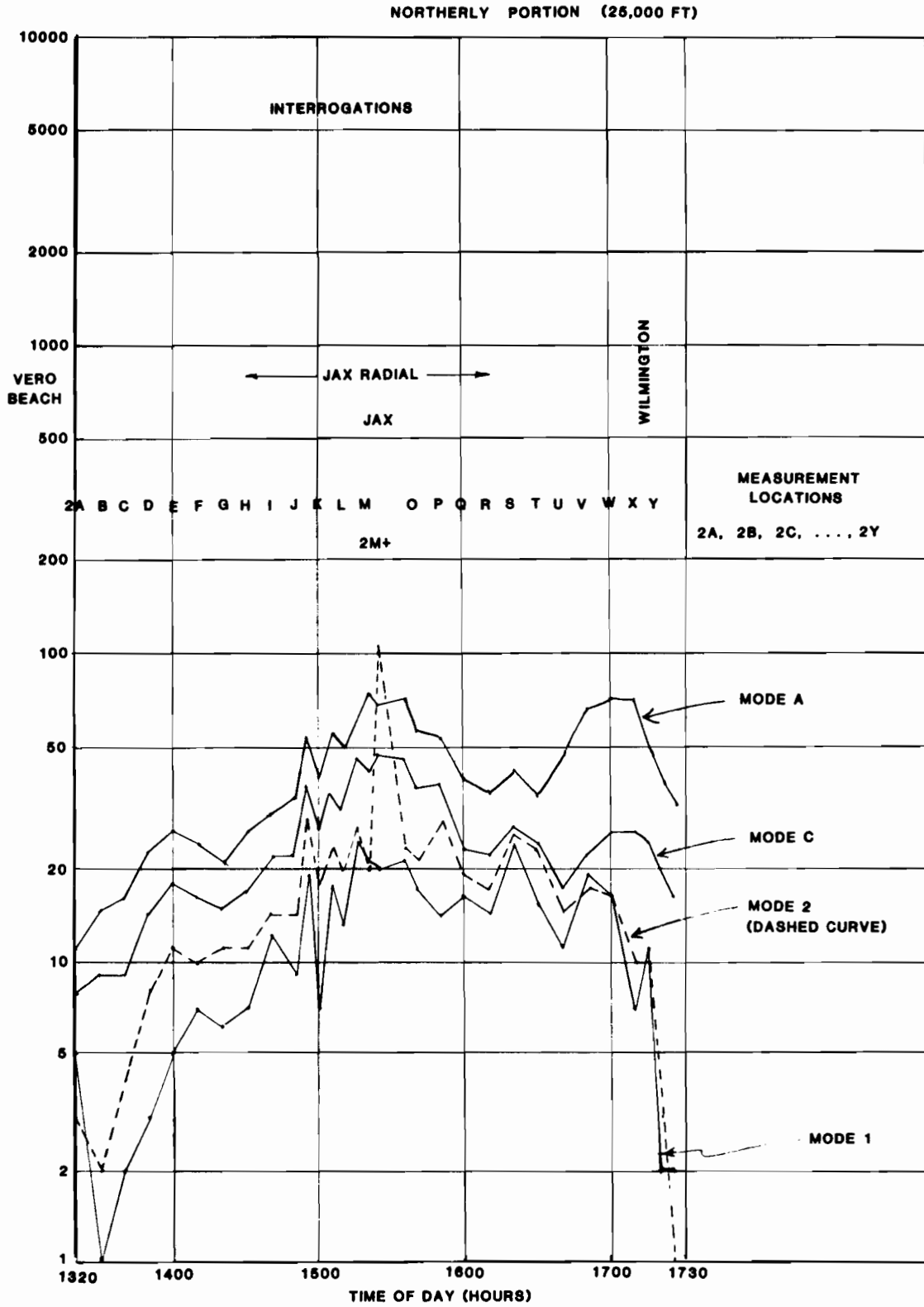
Combined Interrogation Rates over the Ocean
Figure 5

Fig. 2 shows a number of small suppression peaks during the southerly leg of the flight. The first one, around 600 suppressions per second (SPS), is in the Charleston-Savannah region. The second peak 900 SPS is at location 1L, near Jacksonville International. The third peak of about 800 SPS is noted again just to the south of JAX on the second approach to that point (after completing the 50 nmi circle). The largest suppression peak of 1300 SPS is observed near Cape Canaveral. The suppression rate remains high as Patrick AFB is passed.

The northerly leg of the flight (Fig. 4) produced only a single suppression peak of about 900 SPS at location 2M+, the nearest point of the 95 degree radial to JAX. The figure displays a number of suppression rate nulls or troughs (10 or less suppression per second at several locations).

To estimate the number of interrogators contributing to the observed rates of suppression, note that a single interrogator using ISLS contributes about 300 SPS to aircraft in its vicinity. There is, of course, always the possibility that only a portion of the suppression pulses from any one interrogator on ISLS are seen, or that a portion of the suppressions come from interrogators using regular SLS.

## 2.3 Interrogation Rates

Figures 3 and 5 giving the interrogation rates for the two legs of the flight, show two general trends associated with interrogation rates: (1) they tend to remain more uniform than suppression rates do, and (2) Mode A is observed about twice as often as Mode C, and about four times as often as Mode 2. The first trend results from the fact that the P1-P3 pulses are transmitted on the directional antennas, with their higher peak power and longer-range visibility. The second trend results from the preferred FAA interlace modes of AAC for terminal interrogators, and 2ACA for en-route interrogators.

Figure 3 shows that the southerly portion of the flight produced about 40 Mode A interrogations per second (IPS) , with Mode C and Mode 2 -Mode 1 rates correspondingly lower. What appears to be the main exception to the uniformity at the beginning of the flight (between Wilmington and Charleston), is the result of a single military interrogator (the long-range Air Force interrogator at Ft. Fisher, NC), close to the AMF, on 241 PRF, Modes 2ACA, without P2 pulses. 100 percent of its sidelobe interrogations are received at first (120 Mode A's and 60 Mode 2's and Mode C's per second).

Figure 5 shows that the northerly flight at 25,000 ft. produced interrogation rates which increase fairly uniformly to a peak of 60-70 Mode A's at the part of the two-way 95 degree radial nearest to JAX. The one exception is the high burst of Mode 2's at location 2M+, 6-8 nmi cast of JAX. This was due to an interrogator at Mayport, 5 nmi south of the AMF, on 657 PRF. The high Mode A peak near the end of the flight (before Wilmington, locations 2V to 2X) is the result of a single interrogator to the north of the AMF, interrogating on a PRF of 1100 (Mode A, 3.94-sec. scan) contributing 20 Mode A interrogations per second.

## 2.4 Number of Interrogators Seen

Going south, the number of interrogators observed varied from a low of 8 near Jacksonville International (loc. 1R) to highs of 18 near Daytona Beach (Fla) (loc. 1U) and 19 near Savannah (Ga) (loc. 1H). Going north at 25,000 ft. (and disregarding the endpoints) the lowest number (9) of interrogators was seen at loc. 2G, 200 nmi east of the Coast, and the highest number (31) at loc. 2M+, at the Coast. The averages were 13.5 and 17 for the two legs of the flight.

## 2.5 Summary of Total Counts

| | | Observed Average Per Second Rates | |
| --- | --- | --- | --- |
| | | Southerly Leg | Northerly Leg |
| Total Pulses | Max. Rate | 9082 | 5305 |
| | Min. Rate | 1693 | 273 |
| Sum of Mode A and C Ingerrogations | Max. Rate | 235 | 115 |
| | Ave. Rate | 87 | 68 |
| | Min. Rate | 22 | 19 |
| Total Suppressions | Max. Rate | 1302 | 851 |
| | Min. Rate | 61 | 8 |
| Number of Interrogators Observed | Maximum | 19 | 31 |
| | Average | 13.5 | 17 |
| | Minimum | 8 | 9 |

The highest observed civilian (Mode A plus Mode C) interrogation rate (235 IPS) would cause an average transponder to be unavailable for 235 x 60 µs = 0.0141 sec (or 1.41 percent of the time). Similarly, the highest observed suppression rate (1302 SPS), would cause an average transponder to be unavailable for 1302 x 35 µs = 0.0456 sec (or 4.56 percent of the time).

Thus the average interrogation and suppression rates observed are not high enough to cause a problem unless they peak much higher than their measured average values in any measurement interval or unless they are synchronous with the PRI of one of the FAA interrogators of the Jacksonville area. High instantaneous rates are discussed further in Sections 3.9 and 3.10, as well as in Sections 6.8 and 6.9. Synchronous interference is discussed in Section 7.2.5.

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## 3.0 INTERROGATORS OBSERVED DURING THE JACKSONVILLE FLIGHT

### 3.1 Section Outline

Data on the 59 interrogators observed during the 23 May 1979 flight of the AMF are presented in this section. Specifically included are:

● A list of the interrogators and their major parameters (Fig. 6). This list serves as an all-location/ all-interrogator visibility matrix (37 measurement locations x 59 interrogators).

● A list of the interrogators arranged by PRI (and PRF) (Table 3).

● A list of the actual PRI for interrogators on staggered but not random PRI (Fig. 7).

● A master list of local individual results (Interrogations/min. AOA, Ave and Pk Power) in the form of two inverted visibility matrices where the columns are the interrogators, and the rows are, in the first case, 24 measurement locations 1A, 1B, ....., 1X along the southerly flight of the AMF (Table 4A), and, in the second case, 13 odd measurement locations 2A, 2C, 2G,....2Y along the return flight (Table 4B).

● Three PRI/PRF distributions of the interrogations received in 1 minute at locations 1H, 1U, and 2M+ (Fig. 8 and Table 5).

● A list of the reflections observed during the flight (Table 6).

● A list of Mode 4 interrogations observed during the flight (Table 7).

● Four plots showing pulse-by-pulse plots of over 50 Mode 4 interrogations received from Ft. Fisher, Jacksonville NAS (Interrogator 24) and Patrick ARSR (at locations 1B, 1K, 1S and 1X), with the sequence of effects (interrogations or suppressions) on an average transponder (Figures 9a to 9d).

● Five plots showing the high instantaneous interrogations rates at locations 1G, 1H and 2N+ where reply rate limiting (RRL) and/or track loss may occur (Figures 10a to 10e).

● Three plots showing high instantaneous suppression rates (at locations 1L, 1V, and 1W), which may interfere with transponder availability (Figures 11a to 11c).

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## 3.2. The All-Location/All-Interrogator Visibility Matrix (Fig. 6)

The 2-part Figure 6, headed by the 24 location codes 1A through 1X of the southerly leg of the flight, and by the 13 location codes 2A through 2Y of the northerly leg, is an overall visibility matrix for the 59 interrogators*. A "dot" (.) at any point in the matrix indicates that the interrogator to the right is not visible at the location involved. The visibility numbers represent the approximate local interrogation rate of each interrogator as a power of 2. The exact correspondence between the powers, expressed as hexideximal numbers, and the ranges of the interrogations per minute are shown on the figure (small box along lower edge of part 1). Additional information on interrogator PRI is given in Table 3 and Figure 7.

The visibility matrix may be used to answer the following questions (note that each row of the visibility matrix is an interrogator, each column, a measurement location):

- How many interrogators are present at a given location, and which ones are they? (Examine the corresponding columns).

- Is a given interrogator present at a given location? (Examine a single intersection).

- What is the run length (length of visibility) of a particular interrogator for the complete flight? (No. of entries -- contiguous or otherwise -- in the corresponding row).

- How heavily does a particular interrogator contribute to the interrogation environment? (Examine the actual values of the powers in the corresponding column).

- What interrogators are not using SLS? (Presence of large entries in a particular row).

- Is there a close approach to a non-SLS interrogator? (Presence of a sharp peak in the corresponding row).

- What measurement location is nearest to an interrogator with limited visibility (dots on both ends)? (Middle entry of the row, discounting entries 1L to 1Q (the JAX circle) and entries 2I to 2Q (the JAX radial), if indicated).

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*The interrogators were numbered in order of their discovery. The 15 interrogators seen at location 1A, for example, were numbered 1 through 15, and so on (there are a few exceptions to this). Numbers are assigned from 1 to 62, three more than the number of interrogators seen. The reason is that 3 of the 62 (numbers 34, 50, and 53) were found not to be separate interrogators as was first supposed.

| 1-MINUTE AMF MEASUREMENT LOCATIONS | | DESCRIPTION OF INTERROGATORS OBSERVED | | | | | | |
| SOUTHERLY (INLAND) LEG | OCEAN LEG | | | | | | | |
| ABCDEFGHIJKLMNOPQRSTUVWX | ACEGIKMOQSUWY | NO | SUSP. NAME OR LOC | PRI (US) | PRF | MODES | SCAN | ST |
|---|---|---|---|---|---|---|---|---|
| 8......................... | ..........78 | 1 | Airborne Near 2Y | 3335 | 299.8 | 2*AC | 3.86 | 1 |
| 7......................... | ...........7 | 2 | Pope AFB | 3654 | 273.6 | AAC | 3.85 | 1 |
| 85........................ | ..........88 | 3 | Bogue MCALF | 2676 | 373.6 | AC | 3.91 | 1 |
| 8887...................... | .........688 | 4 | Benson ARSR | 2700 ±7 | 370.3 | AC | 10.12 | 5 |
| 687....................... | ............ | 5 | Myrtle Beach AFB | 4000- | 250.0 | 1AC | 9.31 | 1 |
| 87........................ | ..........58 | 6 | Near 2Y | 3991 ave | 250.6 | AC | 4.68 | 3 |
| 8868...................... | .........789 | 7 | Jacksonville N.C. | 2530 | 395.2 | A | 4.04 | 1 |
| 8888...................... | .........578 | 8 | Fayetteville ASR | 2625 | 380.9 | AAC | 3.92 | 1 |
| 99887..................... | ............ | 9 | Myrtle Beach AFB | 3331 | 300.2 | AC | 4.67 | 1 |
| 67778777.................. | .........5.6 | 10 | Shaw AFB | 3328(9) | 300.4 | AC | 3.92 | 1 |
| 7.888888.................. | .........8. | 11 | Columbia ASR-7 | 2245 ave | 445.4 | AAC | 4.68 | 8 |
| 6888A8885................. | ....57866778. | 12 | Charleston ASR | 2566 | 389.6 | A | 4.70 | 1 |
| 778888887......7......... | ....787677787 | 13 | Jedburg ARSR | 2901 ±7 | 344.7 | AC | 12.02 | 5 |
| 8899B988887....76........ | ..67888888898 | 14 | No. Charleston | 3040 | 328.9 | 2ACA/4 | 11.75 | 1 |
| EEDC77.67..........4... | ....76..6.888 | 15 | Ft. Fisher | 4146 | 241.2 | 2ACA/4 | 11.98 | 1 |
| ..77..................... | ............ | 16 | Near Charleston | 2458 ±1 | 406.8 | 2 | 3.92 | 1 |
| ..67777674.....5......... | ......65..66. | 17 | Aiken AFS ARSR | 4135 | 241.8 | AC | 12.04 | 1 |
| ...9ABDBA99...7A7........ | ............ | 18 | Beaufort MCAS | 3251(2) | 307.5 | 12AC | 9.82 | 1 |
| ...89999988....96........ | ....98898767. | 19 | Beaufort MCAS | 4588 ave | 218.0 | 2*12AC | 9.59 | 12 |
| ....89.9999A9AAAA..AA98. | ........AA... | 20 | Shipborne Near 2K | 3133±150 | 319 ± | 4*12AC | 3.82 | Rm |
| ....88885................. | ............ | 21 | Augusta ASR | 2531 | 395.0 | AAC | 3.92 | 1 |
| ....89.AA997A.999989A87. | 989A99995A99. | 22 | Shipborne Near 2K | 3415 ave | 292.8 | 4*12AC | 7.85 | 9 |
| .....9AB8.....7........... | ........6.6... | 23 | Statesboro | 2440-1 | 409.7 | 1 | 8.83 | 1 |
| .....579889A98989999987. | .7988988887.. | 24 | Jacksonville NAS | 2819 | 354.7 | 2ACA/4 | 12.02 | 1 |
| .....8877888.7788....... | .:.....778.5.. | 25 | Savannah ASR | 3095 ±7 | 323.1 | A | 4.70 | 5 |
| .....7........8...9...8. | ............ | 26 | Shipborne Near 2K | 4048-9 | 247.0 | 4*12AC | 7.90 | 1 |
| .....5................... | ............ | 27 | AWACS | 5005-74 | 200- | 2AC | | Rm |
| .......6768887888787.... | .....587..... | 28 | Valdosta ARSR | 2700- | 370.3 | AC | 11.98 | 1 |
| .....68888877888777875. | ..77778777... | 29 | Whitehouse ARSR | 2741±7 | 364.8 | AAC | 12.02 | 5 |
| ......788888888878877.. | ..77878877... | 30 | Jacksonv.Intern. ASR | 2969 ±7 | 336.8 | AAC | 4.70 | 5 |
| ABCDEFGHIJKLMNOPQRSTUVWX | ACEGIKMOQSUWY | | | | | | | |

BASIC INTERROGATOR LIST AND VISIBILITY MATRIX

Figure 6 (1st half)

| INT/MIN RANGES FOR POWER P | I/MIN | P |
|---|---|---|
| | 24576 | E |
| | 12288 | D |
| | 6144 | C |
| | 3072 | B |
| | 1536 | A |
| | 768 | 9 |
| | 384 | 8 |
| | 192 | 7 |
| | 96 | 6 |
| | 48 | 5 |
| | 24 | 4 |
| | 12 | |

| ABCDEFGHIJKLMNOPQRSTUVWX | ACEGIKMOQSUWY | NO | SUSP. NAME OR LOC | PRI (US) | PRF | MODES | SCAN | ST |
|---|---|---|---|---|---|---|---|---|
| .......7888988888888885. | ..76888987... | 31 | Jacksonville NAS | 3461 | 288.9 | 2AC | 3.92 | 1 |
| ........767...787....... | ....78888678. | 32 | Beaufort MCAS | 2594 | 385.4 | 2/AC | 3.93 | 1 |
| ........7888787788787.. | ......888.... | 33 | Cecil NAS | 2663-4 | 375.4 | AAC | 3.92 | 1 |
| ........................ | ............. | 34 | (Not Used) | | | | | |
| .........686...4788888. | .78.678777... | 35 | Daytona Beach ASR | 2559.7 | 390.7 | AAC | 3.92 | 1 |
| ...........77.......... | ......77..... | 36 | Tallahassee ASR | 2498.5 | 400.2 | AAC | 3.92 | 1 |
| ...............47........ | ......8...... | 37 | Macon ASR (Robins) | 2500.8 | 399.9 | AAC | 4.68 | 1 |
| ..................88987. | ......87..... | 38 | Astor Park | 2275 ±7 | 439.5 | AC | 2.80 | Rm |
| ....................778888 | 88887787776.. | 39 | Patrick AFB ARSR | 2776 ±7 | 360.2 | 2ACA/4 | 12.01 | 5 |
| ....................777788 | 887777777.6.. | 40 | Patrick AFB ASR | 3342 | 299.2 | AC | 3.92 | 1 |
| .....................88888 | 788..7777.... | 41 | Orlando ASR | 2626 | 380.7 | AAC | 4.71 | 1 |
| .....................778. | ......77..... | 42 | Tampa ASR | 2884 | 346.7 | AAC | 4.70 | 1 |
| ..................8... | ............. | 43 | Daytona Ramp Tester | 3064-5 | 326.3 | A | 2.18 | 1 |
| ..................767. | .4....67..... | 44 | Mac Dill AFB ARSR | 4147 | 241.1 | 2ACA | 11.98 | 1 |
| ......................6. | ............. | 45 | Sarasota ASR | 2564 | 389.9 | AAC | 4.04 | 1 |
| ......................66 | 767.......... | 46 | W. Palmbeach ASR | 3049 | 327.9 | AAC | 4.71 | 1 |
| ........................ | .6........... | 47 | Richmond AFS ARSR | 2820.0 | 354.6 | 2ACA/4 | 10.11 | 1 |
| ........................ | ..99999A..... | 48 | Shipborne Near 2K | 3052-61 | 327 ± | 4*12AC | 3.80 | 1 |
| ........................ | ......9...... | 49 | Mayport NS | 1522 ±4 | 657 | A/1/2 | 7.18 | Rm |
| ........................ | ............. | 50 | (Not Used) | | | | | |
| .....................6.8. | ......76..... | 51 | Mac Dill AFB | 4000 | 250.0 | 2*AC | 9.32 | 1 |
| .....................777. | ......66..... | 52 | Mac Dill AFB | 3991 ave | 250.6 | AC | 4.70 | 3 |
| ........................ | ............. | 53 | (Not Used) | | | | | |
| ........................ | ........A89. | 54 | Shipborne Near 2K | 4129-30 | 242.1 | 4*12AC | 7.90 | 1 |
| ........................ | ..........9A. | 55 | Near Myrtle Beach | 912 | 1096 | A | 3.94 | 1 |
| ........................ | ..........57. | 56 | Bogue MCALF | 7506.4 | 133.2 | A | 6.37 | 1 |
| ........................ | ...........777 | 57 | Nr Seym.Johnson AFB | 3991 ave | 250.6 | AC | 4.68 | 3 |
| ........................ | ...........6. | 58 | Charlotte ASR | 2626.8 | 380.7 | AAC | 4.70 | 1 |
| ........................ | ...........7 | 59 | Maiden ARSR | 2778 ±7 | 359.9 | AC | 12.02 | 5 |
| ........................ | ............. | 60 | Panama City ARSR | 2818 ±7 | 354.9 | 2ACA | 12.02 | 5 |
| ........................ | ............. | 61 | West of Loc. 2M+ | 3502-3 | 285.5 | AC | 3.94 | 1 |
| ........................ | ............. | 62 | South of Loc. 2M+ | 3650 | 273.9 | AC | 3.85 | 1 |
| ABCDEFGHIJKLMNOPQRSTUVWX | ACEGIKMOQSUWY | | | | | | | |

BASIC INTERROGATOR LIST AND VISIBILITY MATRIX

Figure 6 (2nd half)

FOR ALL LOCATIONS OF VISIBILITY, INT/MIN ARE GIVEN TO NEAREST POWER OF 2. SUBTRACT 6 FROM GIVEN POWERS (DIVIDE BY 64) TO OBTAIN INT/SEC.

TABLE   3

JACKSONVILLE AREA INTERROGATORS ARRANGED BY PRI / PRF

PART 1: (PRI under 3000 µs / PRF over 333.3 IPS)

DESCRIPTION OF INTERROGATORS OBSERVED

| NO. | SUSP. NAME OR LOC. | PRI (US) | PRF | MODES | SCAN | ST | PRI ORDER |
|-----|--------------------|----------|-----|-------|------|-----|-----------|
| 55 | Near Myrtle Beach | 912 | 1096 | A | 3.94 | 1 | 1 |
| 49 | Mayport NS | 1522 ±4 | 657 | A/1/2 | 7.18 | Rm | 2 |
| 11 | Columbia ASR-7 | 2245 ave | 445.4 | AAC | 4.68 | 8 | 3 |
| 38 | Astor Park | 2275 ±7 | 439.5 | AC | 2.80 | Rm | 4 |
| 23 | Statesboro | 2440-1 | 409.7 | 1 | 8.83 | 1 | 5 |
| 16 | Near Charleston | 2458 ±1 | 406.8 | 2 | 3.92 | 1 | 6 |
| 36 | Tallahassee ASR | 2498.5 | 400.2 | AAC | 3.92 | 1 | 7 |
| 37 | Macon ASR (Robins) | 2500.8 | 399.9 | AAC | 4.68 | 1 | 8 |
| 7 | Jacksonville NC | 2530 | 395.2 | A | 4.04 | 1 | 9 |
| 21 | Augusta ASR | 2531 | 395.0 | AAC | 3.92 | 1 | 10 |
| 35 | Daytona Bch ASR | 2559.7 | 390.7 | AAC | 3.92 | 1 | 11 |
| 45 | Sarasota ASR | 2564 | 389.9 | AAC | 4.04 | 1 | 12 |
| 12 | Charleston ASR | 2566 | 389.6 | A | 4.70 | 1 | 13 |
| 32 | Beaufort MCAS | 2594 | 385.4 | 2/AC | 3.93 | 1 | 14 |
| 8 | Fayetteville ASR | 2625 | 380.9 | AAC | 3.92 | 1 | 15 |
| 41 | Orlando ASR | 2626 | 380.7 | AAC | 4.71 | 1 | 16 |
| 58 | Charlotte ASR | 2626.8 | 380.7 | AAC | 4.70 | 1 | 17 |
| 33 | Cecil NAS | 2663-4 | 375.4 | AAC | 3.92 | 1 | 18 |
| 3 | Bogue MCALF | 2776 | 73.6 | AC | 3.91 | 1 | 19 |
| 28 | Valdosta ARSR | 2700- | 370.3 | AC | 11.98 | 1 | 20 |
| 4 | Benson ARSR | 2700 ±7 | 370.3 | AC | 10.12 | 5 | 21 |
| 29 | Whitehouse ARSR | 2741 ±7 | 364.8 | AAC | 12.02 | 5 | 22 |
| 39 | Patrick AFB ARSR | 2776 ±7 | 360.2 | 2ACA/4 | 12.01 | 5 | 23 |
| 59 | Maiden ARSR | 2778 ±7 | 359.9 | AC | 12.02 | 5 | 24 |
| 60 | Panama City ARSR | 2818 ±7 | 354.9 | 2ACA | 12.02 | 5 | 25 |
| 24 | Jacksonville NAS | 2819 | 354.7 | 2ACA/4 | 12.02 | 1 | 26 |
| 47 | Richmond AFB ARSR | 2820.0 | 354.6 | 2ACA | 10.11 | 1 | 27 |
| 42 | Tampa ASR | 2884 | 346.7 | AAC | 4.70 | 1 | 28 |
| 13 | Jedburg ARSR | 2901 ±7 | 344.7 | AC | 12.02 | 5 | 29 |
| 30 | Jacksonville Int. ASR | 2969 ±7 | 336.8 | AAC | 4.70 | 5 | 30 |

## TABLE 3

### JACKSONVILLE AREA INTERROGATORS ARRANGED BY PRI/PRF

#### PART 2: (PRI over 3000 µs / PRF under 333.3 IPS)

DESCRIPTION OF INTERROGATORS OBSERVED

| NO. | SUSP. NAME OR LOC. | PRI (US) | PRF | MODES | SCAN | ST | PRI ORDER |
|-----|--------------------|----------|-----|-------|------|-----|-----------|
| 14 | No. Charleston | 3040 | 328.9 | 2ACA | 11.75 | 1 | 31 |
| 46 | W. Palmbeach ASR | 3049 | 327.9 | AAC | 4.71 | 1 | 32 |
| 48 | Shipborne Near 2K | 3060-1 | 326.7 | 4*12AC | 3.80 | 1 | 33 |
| 43 | Daytona Ramp Tester | 3064-5 | 326.3 | A | 2.18 | 1 | 34 |
| 25 | Savannah ASR | 3095 ±7 | 323.1 | A | 4.70 | 5 | 35 |
| 20 | Shipborne Near 2K | 3153±150 | 317.± | 4*12AC | 3.82 | Rm | 36 |
| 18 | Beaufort MCAS | 3251 (2) | 307.5 | 12AC | 9.82 | 1 | 37 |
| 10 | Shaw AFB | 3328 (9) | 300.4 | AC | 3.92 | 1 | 38 |
| 9 | Myrtle Beach AFB | 3331 | 300.2 | AC | 4.46 | 1 | 39 |
| 1 | Airborne Near 2Y | 3335 | 299.8 | 2*AC | 3.86 | 1 | 40 |
| 40 | Patrick AFR ASR | 3342 | 299.2 | AC | 3.92 | 1 | 41 |
| 22 | Shipborne Near 2K | 3415 ave | 292.8 | 4*12AC | 7.85 | 9 | 42 |
| 31 | Jacksonville NAS | 3461 | 288.9 | 2AC | 3.92 | 1 | 43 |
| 61 | West of Loc. 2M+ | 3502-3 | 285.5 | AC | 3.94 | 1 | 44 |
| 62 | South of Loc. 2M+ | 3650 | 273.9 | AC | 3.85 | 1 | 45 |
| 2 | Pope AFB | 3654 | 273.6 | AAC | 3.85 | 1 | 46 |
| 6 | Near Loc. 2Y | 3991 ave | 250.6 | AC | 4.68 | 3 | 47 |
| 52 | Mac Dill AFB | 3991 ave | 250.6 | AC | 4.70 | 3 | 48 |
| 57 | Nr. Seym. Johnson AFB | 3991 | 250.6 | AC | 4.68 | 3 | 49 |
| 5 | Myrtle Beach AFB | 4000- | 250.0 | 1AC | 9.31 | 1 | 50 |
| 51 | Mac Dill AFB | 4000 | 250.0 | 2*AC | 9.32 | 1 | 51 |
| 26 | Shipborne Near 2K | 4048-9 | 247.0 | 4*12AC | 7.90 | 1 | 52 |
| 54 | Shipborne Near 2K | 4129-30 | 242.1 | 4*12AC | 7.90 | 1 | 53 |
| 17 | Aiken AFB ARSR | 4135 | 241.8 | AC | 12.04 | 1 | 54 |
| 15 | Ft. Fisher | 4146 | 241.2 | 2ACA/4 | 11.98 | 1 | 55 |
| 44 | Mac Dill AFB ARSR | 4147 | 241.1 | 2ACA | 11.98 | 1 | 56 |
| 19 | Beaufort MCAS | 4588 ave | 218.0 | 2*12AC | 9.59 | 12 | 57 |
| 27 | AWACS | 5005-74 | 200.0 | 2AC | | Rm | 58 |
| 56 | Bogue MCALF | 7506.4 | 133.2 | A | 6.37 | 1 | 59 |

| No. 19<br>Beufort MCAS<br>(12-Pulse-Stagger) | No. 11<br>Columbia ASR-7<br>(8-Pulse-Stagger) | No. 22<br>Shipborne Near 2K<br>(9-Pulse-Stagger) |
|---|---|---|
| 3774.5 | 1805.625 | 2831.625 |
| 3774.625 | 1885.625 | 2831.625 |
| 3774.625 | 2295.5 | 3051.375 |
| 6000.875 | 2858.375 | 2831.75 |
| 3774.375 | 2235.625 | 2831.625 |
| 3774.5 | 1845.625 | 3881.375 |
| 3774.5 | 1905.5 | 2831.75 |
| 4720.0 | 3128.375 | 2831.625 |
| 3774.375 | | 6810.75 |
| 3774.75 | | |
| 3774.375 | | |
| 10362.5 | | |

| No. 4<br>Benson ARSR<br>(5-Pulse-Stagger) | No. 25<br>Savannah ASR<br>(5-Pulse-Stagger) | No. 30<br>Jacksonville International<br>(5-Pulse-Stagger) |
|---|---|---|
| 2693.75 | 3088.25 | 2962.25 |
| 2704.5 | 3099.0 | 2973.0 |
| 2701.0 | 3095.5 | 2969.375 |
| 2697.375 | 3091.875 | 2965.875 |
| 2708.125 | 3102.625 | 2976.625 |

| No. 13<br>Jedburg ARSR<br>(5-Pulse-Stagger) | No. 29<br>Whitehouse ARSR<br>(5-Pulse-Stagger) | No. 39<br>Patrick ARSR<br>(5-Pulse-Stagger) |
|---|---|---|
| 2893.75 | 2734.125 | 2769.0 |
| 2904.625 | 2745.0 | 2779.875 |
| 2901.0 | 2741.375 | 2776.25 |
| 2897.375 | 2737.75 | 2772.5 |
| 2908.25 | 2748.625 | 2783.5 |

| No. 6 (Near 2Y)<br>No. 57 Nr. Seymore<br>Johnson AFB<br>No. 52 Mac Dill AFB<br>(3-Pulse-Stagger) | No. 59<br>Maiden ARSR<br>(5-Pulse-Stagger) | No. 60<br>Panama City ARSR<br>(5-Pulse-Stagger) |
|---|---|---|
| | 2770.875 | 2810.875 |
| | 2781.875 | 2821.75 |
| 3691.25 | 2778.25 | 2818.0 |
| 4101.0 | 2774.625 | 2814.5 |
| 4181.125 | 2785.5 | 2825.25 |

Actual PRI of Interrogators on Staggered PRI ($\mu$s)
Four Random Staggers Excluded
Figure 7

## 3.3 Basic Parameters of the Interrogators

In addition to indicating visibility, Figure 6 displays the following parameters for each interrogator:

- Suspected name or location and type.

- Pulse Repetition Interval (PRI in μs). This is an average value, if the PRI is staggered. When possible, the total excursion in PRI is shown (e.g., 5-pulse-stagger ± 7).

- Pulse Repetition Frequency (PRF).

- Mode Interlace with indication of use of Mode 4. Maximum length handled = 16. (4*12AC denotes 11112222AAAACCCC).

- Scan Period (sec) of the antenna.

- Length of the Stagger Period (ST) for interrogators on finite stagger. "Rm" implies random stagger.

The AMF uplink analysis program cannot assign names to the interrogators (internal PRF tracks) it detects at a a given location; neither can it remember interrogators seen at other locations as it goes through its analysis of 60-second recordings at each place. The job of correlating the data provided at each location (no. of interrogations, received power, angle of arrival, mode interlace and scan period for a given PRF) with similar data at other locations, and eventually, with ECAC, IRAC, and FAA-supplied interrogator lists, was done by hand.

### 3.3.1 FAA Interrogators

Of the 59 interrogators listed in Figure 6, 25 are marked as FAA interrogators. Ten of these are en-route interrogators (ARSR's), eight on a 12-sec scan, the other two (Benson and Richmond) on the faster 10-sec scan. The remaining fifteen FAA interrogators are terminal interrogators (ASR's), with scan periods of: (a) 4.69 sec. (9); (b) 3.92 sec. (5); and (c) 4.04 sec. (1).

FAA terminal and enroute interrogators usually are not colocated. The only exception noted is the pair of interrogators at Patrick AFB.

The FAA has recently been replacing the ASR-7 terminal interrogators (on 8-pulse stagger using one of six crystals tuned one percent apart) with ASR-8's on fixed PRF's. The only ASR-7 remaining in service in the area is located in West Columnbia S.C. (our interrogator 11). This shows that the FAA replacement plan has been almost completely carried out.

Preliminary antenna plots (not included in this report) for some of the FAA interrogators show that the Jedburg and Whitehouse ARSR's use regular SLS, while the ARSR at Patrick AFB uses improved SLS (ISLS). The opposite indication is given for these in the ECAC file.

Antenna plots also show the ASR's at Charleston, Savannah and Jacksonville International using ISLS, and the ASR at Patrick AFB using regular SLS. These four are in agreement with the ECAC file.

The same preliminary antenna plots also showed many sidelobe punch-throughs for Charleston ASR and Patrick ARSR, numerous punch-throughs for Jacksonville International, very few punch-throughs for the Savannah ASR and the Jedburg and Whitehouse ARSR's.

### 3.3.2 Non-FAA Interrogators

Thirty-four of the 59 interrogators were thought to be non-FAA interrogators. These were located as follows:

#### (1) Interrogators at Sea

Interrogators numbered 20, 22, 26, 48, and 54 appear to be located on ships in the Atlantic Ocean, about 90 to 100 nmi east of Whitehouse ARSR. All of these used mode interlace 11112222AAAACCCC (they were the only interrogators using this pattern). Interrogators 20 and 48 (both with scan periods of 3.8 sec) may be the same interrogator even though they use different stagger and different PRI, since the two were never seen simultaneously.

Similarly, interrogators 26 and 54 (both with scan periods of 7.90 sec) might actually be a single interrogator using two slightly different PRF's (247.0 vs 242.1) since these two are also not "on" at the same time. Interrogator 22 is on a remarkable 9-pulse stagger noted in earlier flights (see Figure 7 for details).

#### (2) Beaufort MCAS

Interrogators 18, 19, and 32 seem to be located at Beaufort MCAS. The first one of these, without the benefit of SLS, contributed the second highest interrogation rate seen (133/sec at location 1G, on a PRF of 307.5). The second one (number 19), on an average PRF of 218, demonstrated the most complicated (12-pulse) stagger seen during the flight (see Figure 7 for the details).

#### (3) Ft. Fisher

The highest interrogation rate observed (240/sec at location 1A came from Ft. Fischer, a long range coastal interrogator near location 2X. Curiously, at the end of the flight, at comparable distance and peak received power, the rate was down to 5/sec. Ft. Fisher apparently has SLS (as indicated in the ECAC file), which it did not use early in the morning, but did use later in the day.

### (4)  Mayport Naval Station

Interrogator 49, located (perhaps aboard a ship) at Mayport Naval Station, had the second highest PRF (657) observed during the flight. This is like two interrogators on an average PRF. The only reason it did not contribute an excessive amount is because it went "blank" eight times after every four interrogations, lowering its duty ratio to one third. This interrogator was discovered at location 2M with mode interlace AAAA for the first 4 mainbeams and modes 1111 on the 5th mainbeam. At 2M+ it used mode interlace 2222 exclusively.

Interrogator 49 uses no SLS, and it could become a real problem, if it went back to 100 percent duty factor, used civilian modes A and C only for some interval of time, and increased its transmitted power. It is likely to do all these things some of the time.

### (5)  Interrogator 55 Near Myrtle Beach

This is a very normal looking interrogator transmitting mode A at a scan period of 3.94 sec. It is of interest because it uses the highest PRF (1096 int/sec) seen anywhere during the flight. Note that this PRF is the third harmonic of a popular PRF (365.3), used for example, by Whitehouse ARSR (364.8 exactly). This interrogator does use SLS (at least during the time we observed it), and contributes only 21 int/sec, instead of possibly 50 times as many without SLS.

### (6)  Bogue and Jacksonville (NC)

Interrogators numbered 3 and 56 were thought to be located at Bogue Field. The second one had the lowest PRF (133.2) of any interrogator seen, and it is suspected to be using the more usual PRF of 2X133.2 = 267 and blanking out every other interrogation. Interrogators 3 and 56 may be located in Jacksonville, NC (Camp Le Jeune) where scan periods and modes are in better agreement with the ECAC file. Angles of arrival gave Bogue a slight preference. With interrogator 7, there could be a total of three interrogators at Camp Le Jeune, as shown in the ECAC file.

### 3.3.3 Observed PRI/PRF

Figure 6 and Table 3 include (average) PRI and PRF for the 59 interrogators seen. They also indicate stagger lengths for those interrogators which are not on fixed PRF. "Rm" here indicates a non-repeating (random) stagger about some average value. Figure 7 gives measured PRI for all interrogators on staggered but not random PRF. Summary PRI/PRF results follow:

|                    | Number | Percent |
|--------------------|--------|---------|
| 12-Pulse Stagger   | 1      | 2       |
| 9-Pulse Stagger    | 1      | 2       |
| 8-Pulse Stagger    | 1      | 2       |
| 5-Pulse Stagger    | 8      | 14      |
| 3-Pulse Stagger    | 3      | 5       |
| Random  Stagger    | 4      | 7       |
| Staggered PRF's    | 18     | 31      |
|                    |        |         |
| Fixed PRF's        | 41     | 69      |
|                    |        |         |
| Total PRF's        | 59     | 100     |

| Quantity | No. | Interrogator Name | PRF (Ave) | Stagger Lengths |
|----------|-----|-------------------|-----------|-----------------|
| Highest PRF's | 55 | Near Myrtle Beach | 1096.0 | 1 |
|               | 49 | Mayport NS | 657.0 | Random |
|               | 11 | Columbia ASR-7 | 445.4 | 8 |
|               | 38 | Astor Park | 439.5 | Random |
|               |    |            |        |        |
| Lowest PRF's  | 44 | Mac Dill AFB ARSR | 241.1 | 1 |
|               | 19 | Beaufort MCAS | 218.0 | 12 |
|               | 27 | AWACS | 200.0 | Random |
|               | 56 | Bogue MCAS | 133.2 | 1 |
|               |    |            |        |        |
| Median PRF    | 30 | Jacksonville International | 336.8 | 5 |

### 3.3.4 Observed Mode Interlaces

57 out of 59 interrogators used a single mode interlace pattern; two used more than one.  Mayport (number 49) used either A or 1 or 2.   Interrogator 32 (Beaufort  MCAS) used either  mode 2  or mode AC.  With the  three extra mode interlaces,  a total of 59 +  3 =  62 were observed.   Summary mode  interlace results follow:

| Mode Interlace |   | Number | Percent |
|----------------|---|--------|---------|
| AC    | .............. | 16 | 26 |
| AAC   | .............. | 15 | 24 |
| A     | .............. | 7  | 11 |
| 4*12AC | .............. | 5  | 8  |
| 2ACA/4 | .............. | 5  | 8  |
| 2     | .............. | 3  | 5  |
| 1     | .............. | 2  | 3  |
| 2AC   | .............. | 2  | 3  |
| 2ACA  | .............. | 2  | 3  |
| 2*AC  | .............. | 2  | 3  |
| 1AC   | .............. | 1  | 2  |
| 12AC  | .............. | 1  | 2  |
| 2*12AC | .............. | 1  | 2  |
| Total | .............. | 62 | 100 |

The most popular mode interlaces are AC,  AAC, and A (used mostly  by terminal interrogators), and then 2ACA (used entirely by en-route interrogators).

### 3.3.5 Scan Periods

A scan period was measured for all but one of the 59 interrogators observed. The exception was Interrogator 27 (AWACS), for which only a single mainbeam was seen. The following summary results are arranged by length of time. Scan periods grouped together are usually within ± 0.02 sec of the value given.

| Scan Period (sec) | Number | Scan Period (sec) | Number |
|---|---|---|---|
| 2.18 | 1 | 7.85 – 7.90 | 3 |
| 2.80 | 1 | 8.83 | 1 |
| 3.80 – 3.86 | 6 | 9.31 | 2 |
| 3.92 | 13 | 9.59 | 1 |
| 4.04 | 2 | 9.82 | 1 |
| 4.70 | 12 | 10.11 | 2 |
| 6.37 | 1 | 11.75 | 1 |
| 7.18 | 1 | 12.00 | 10 |

Two scan periods were under 3 sec, the ramp tester at Daytona Beach (interrogator 43) with its 2.18-sec scan, and Astor Park (interrogator 38) with its 2.80-sec scan.

The table shows that scan periods 3.92 and 4.70 sec are almost equally popular for terminal interrogators. For en-route interrogators, the 12-second scan period predominates. The table also shows a number of odd scan periods for the military interrogators of the larger Jacksonville area.

### 3.4 Master List (Tables 4A and 4B)

Tables 4A and 4B present, for all interrogators visible at 37 (24 + 13) selected measurement locations, the following major results:

● Number of interrogations per minute;

● Angle of arrival (deg, w. resp. to true North);

● Average received power at the bottom antenna (dBm + 97);

● Peak received power at the bottom antenna (dBm + 97).

Table 4A refers to the southerly (inland) portion of the flight at 10,000 ft.; Table 4B to the northerly portion of the flight over the ocean at 25,000 ft.

25

| NO | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| NAME | AirbNr2 | Pope AFB | BogueMCA | BensonAR | MyrtleAF | Near 2Y | JacksvNC | FaytvASR |
| PRI | 3335 | 3654 | 2676 | 2700±7 | 4000- | 3991 ave | 2530 | 2625 |
| PRF | 299.8 | 273.6 | 373.6 | 370.3 | 250.0 | 250.6 | 395.2 | 380.9 |
| MODES | 2*AC | AAC | AC | AC | 1AC | AC | A | AAC |
| SCAN | 3.86 | 3.85 | 3.91 | 10.12 | 9.31 | 4.68 | 4.04 | 3.92 |
| STAG | 1 | 1 | 1 | 5 | 1 | 3 | 1 | 1 |
| 1A | 199  31<br>95 34 | 116  23<br>10 23 | 228  35<br>95 41 | 225  33<br>8 36 | 84  40<br>250 44 | 240  31<br>0 39 | 247  38<br>85 43 | 232  32<br>355 38 |
| 1B |  |  | 34  24<br>85 | 200  29<br>3 38 | 223  34<br>242 60 | 120  25<br>34 31 | 280  36<br>79 43 | 263  31<br>27 37 |
| 1C |  |  |  | 222  34<br>13 40 | 129  40<br>81 44 |  | 67  26<br>77 27 | 249  27<br>10 34 |
| 1D |  |  |  | 145  22<br>35 28 |  |  | 223  22<br>73 | 203  28<br>36 |
| 1E |  |  |  |  |  |  |  |  |
| 1F |  |  |  |  |  |  |  |  |
| 1G |  |  |  |  |  |  |  |  |
| 1H |  |  |  |  |  |  |  |  |
| 1I |  |  |  |  |  |  |  |  |
| 1J |  |  |  |  |  |  |  |  |
| 1K |  |  |  |  |  |  |  |  |
| 1L |  |  |  |  |  |  |  |  |
| 1M |  |  |  |  |  |  |  |  |
| 1N |  |  |  |  |  |  |  |  |
| 1O |  |  |  |  |  |  |  |  |
| 1P |  |  |  |  |  |  |  |  |
| 1Q |  |  |  |  |  |  |  |  |
| 1R |  |  |  |  |  |  |  |  |
| 1S |  |  |  |  |  |  |  |  |
| 1T |  |  |  |  |  |  |  |  |
| 1U |  |  |  |  |  |  |  |  |
| 1V |  |  |  |  |  |  |  |  |
| 1W |  |  |  |  |  |  |  |  |
| 1X |  |  |  |  |  |  |  |  |

23 May 1979 Jacksonville Area Flight of the AMF (Inland, South, 10,000 Ft)

Quantity Plotted Above:

TABLE 4A (p.1)

| INT/MIN | AVE.P |
|---|---|
| AOA | PK.P |

(Powers: dBm at Bottom Ant + 97)

| NO | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|
| NAME | MyrtleAF | Shaw AFB | ColASR-7 | CharlsAS | JedbrgAR | NoCharls | FtFisher | NrCharls |
| PRI | 3331 | 3328(9) | 2245 ave | 2566 | 2901±7 | 3040 | 4146 | 2458 ±1 |
| PRF | 300.2 | 300.4 | 445.4 | 389.6 | 344.7 | 328.9 | 241.2 | 406.8 |
| MODES | AC | AC | AAC | A | AC | 2ACA/4 | 2ACA/4 | 2 |
| SCAN | 4.67 | 3.92 | 4.68 | 4.70 | 12.02 | 11.75 | 11.98 | 3.92 |
| STAG | 1 | 1 | 8 | 1 | 5 | 1 | 1 | 1 |
| 1A | 404 36 / 252 49 | 59 27 / 288 39 | 180 30 / 280 | 56 25 / 247 29 | 110 28 / 242 30 | 313 34 / 247 47 | 13246 30 / 104 59 | |
| 1B | 431 46 / 244 66 | 168 30 / 268 36 | | 254 31 / 242 35 | 185 34 / 238 39 | 300 39 / 243 47 | 12565 22 / 93 49 | |
| 1C | 209 50 / 87 57 | 173 31 / 315 36 | 310 34 / 293 | 272 33 / 243 40 | 200 37 / 240 42 | 389 37 / 245 48 | 12125 21 / 89 49 | 153 30 / 234 33 |
| 1D | 201 31 / 69 40 | 165 29 / 334 35 | 240 30 / 303 | 308 38 / 235 46 | 242 44 / 267 50 | 444 42 / 235 58 | 3214 17 / 80 39 | 153 34 / 230 40 |
| 1E | 130 26 / 78 28 | 196 29 / 4 40 | 350 37 / 322 | 788 49 / 273 60 | 233 52 / 314 59 | 2297 46 / 215 71 | 163 21 / 76 28 | |
| 1F | | 190 33 / 354 38 | 208 24 / 358 | 274 37 / 50 46 | 220 43 / 21 49 | 551 36 / 55 56 | 159 24 / 75 30 | |
| 1G | | 101 25 / 7 33 | 272 23 / 336 | 268 40 / 66 46 | 210 34 / 38 40 | 354 41 / 58 51 | | |
| 1H | | 127 26 / 12 30 | 310 29 / 330 | 226 29 / 48 36 | 195 29 / 62 34 | 289 37 / 49 46 | 68 15 / 62 31 | |
| 1I | | | | 32 21 / 43 25 | 175 34 / 54 40 | 193 24 / 37 34 | 177 26 / 62 37 | |
| 1J | | | | | 58 23 / 58 26 | 206 27 / 54 33 | | |
| 1K | | | | | | 110 18 / 46 25 | | |
| 1L | | | | | | | | |
| 1M | | | | | | | | |
| 1N | | | | | | | | |
| 1O | | | | | | | | |
| 1P | | | | | 122 22 / 32 33 | 187 30 / 30 39 | | |
| 1Q | | | | | | 65 20 / 43 24 | | |
| 1R | | | | | | | | |
| 1S | | | | | | | | |
| 1T | | | | | | | | |
| 1U | | | | | | | 21 20 / 27 21 | |
| 1V | | | | | | | | |
| 1W | | | | | | | | |
| 1X | | | | | | | | |

23 May 1979 Jacksonville Area Flight of the AMF (Inland, South, 10,000 Ft)

Quantity Plotted Above:
TABLE 4A (p. 2)

| INT/MIN | AVE.P |
|---|---|
| AOA | PK.P |

(Powers: dBm at Bottom Ant + 97)

| NO | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|
| NAME | Aiken AR | BeauftMC | BeauftMC | ShipNr2K | AugustAS | ShipNr2K | Statesbo | JacksvNAS |
| PRI | 4134 | 3251(2) | 4588 ave | 3133±150 | 2531 | 3415 av | 2440-1 | 2819 |
| PRF | 241.8 | 307.5 | 218.0 | 319 ± | 395.0 | 292.8 | 409.7 | 354.7 |
| MODES | AC | 12AC | 2*12AC | 4*12AC | AAC | 4*12AC | 1 | 2ACA/4 |
| SCAN | 12.04 | 9.82 | 9.59 | 3.82 | 3.92 | 7.85 | 8.83 | 12.02 |
| STAG | 1 | 1 | 12 | Rm | 1 | 9 | 1 | 1 |
| 1A | | | | | | | | |
| 1B | | | | | | | | |
| 1C | 55 27 / 291 29 | | | | | | | |
| 1D | 110 42 / 301 49 | 506 29 / 227 34 | 280 28 / 229 33 | | | | | |
| 1E | 140 33 / 311 38 | 863 38 / 237 43 | 453 36 / 239 41 | 305 / 254 26 | 222 27 / 299 30 | 214 23 / 222 27 | | |
| 1F | 98 37 / 316 41 | 1940 32 / 246 49 | 420 43 / 250 49 | 430 / 246 31 | 247 30 / 303 36 | 400 27 / 217 30 | 646 28 / 265 35 | 42 29 / 221 46 |
| 1G | 103 30 / 349 34 | 8208 28 / 341 57 | 416 44 / 343 53 | | 260 29 / 352 34 | | 1019 25 / 301 31 | 175 28 / 225 34 |
| 1H | 86 32 / 351 39 | 2506 25 / 18 45 | 402 35 / 17 40 | 600 / 191 36 | 212 23 / 252 31 | 795 32 / 192 41 | 2240 28 / 311 44 | 655 34 / 218 47 |
| 1I | 115 28 / 346 35 | 833 36 / 53 43 | 485 34 / 54 40 | 400 / 185 37 | 46 22 / 333 27 | 850 30 / 183 41 | 347 22 / 346 31 | 339 42 / 211 51 |
| 1J | 23 22 / 15 26 | 462 27 / 60 32 | 281 26 / 69 30 | 500 / 142 48 | | 755 38 / 144 49 | | 270 46 / 220 56 |
| 1K | | 556 19 / 42 25 | 330 18 / 43 22 | 400 / 110 50 | | 460 36 / 118 44 | | 424 46 / 195 58 |
| 1L | | | | 800 / 78 46 | | 149 33 / 78 40 | | 1032 46 / 191 66 |
| 1M | | | | 600 / 120 46 | | 1086 35 / 114 50 | | 557 40 / 115 60 |
| 1N | | | | 1200 / 76 40 | | | | 383 33 / 114 47 |
| 1O | | 167 26 / 30 | | 900 / 89 49 | | 552 37 / 86 42 | 110 23 / 355 30 | 514 39 / 150 52 |
| 1P | 27 18 / 355 23 | 695 31 / 32 39 | 414 30 / 31 35 | 840 / 145 44 | | 726 39 / 148 48 | | 223 46 / 177 53 |
| 1Q | | 178 16 / 34 21 | 56 16 / 35 18 | 800 / 125 46 | | 728 42 / 125 50 | | 479 45 / 195 61 |
| 1R | | | | | | 770 32 / 95 43 | | 443 49 / 202 65 |
| 1S | | | | | | 327 31 / 65 35 | | 734 41 / 284 66 |
| 1T | | | | 900 / 45 43 | | 630 29 / 32 40 | | 598 43 / 332 62 |
| 1U | | | | 800 / 23 34 | | 890 26 / 21 37 | | 482 33 / 3 48 |
| 1V | | | | 600 / 25 39 | | 215 30 / 26 37 | | 244 39 / 10 48 |
| 1W | | | | 300 / 28 28 | | 134 22 / 31 29 | | 171 29 / 14 40 |
| 1X | | | | | | | | |

23 May 1979 Jacksonville Area Flight of the AMF (Inland, South, 10,000 Ft)

Quantity Plotted Above:

TABLE 4A (p. 3)

| INT/MIN | AVE.P |
|---|---|
| AOA | PK.P |

(Powers: dBm at Bottom Ant + 97)

| NO | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 |
|---|---|---|---|---|---|---|---|---|
| NAME | SavnnhAS | ShipNr2K | AWACS | ValdosAR | WhitehAR | JackInAS | JacksNAS | BeauftMC |
| PRI | 3095±7 | 4048-9 | 5005-74 | 2700- | 2741 ±7 | 2969 ±7 | 3461 | 2594 |
| PRF | 323.1 | 247.0 | 200- | 370.3 | 364.8 | 336.8 | 288.9 | 385.4 |
| MODES | A | 4*12AC | 2AC | AC | AAC | AAC | 2AC | 2/AC |
| SCAN | 4.70 | 7.90 | | 11.98 | 12.02 | 4.70 | 3.92 | 3.93 |
| STAG | 5 | 1 | Rm | 1 | 5 | 5 | 1 | 1 |
| 1A | | | | | | | | |
| 1B | | | | | | | | |
| 1C | | | | | | | | |
| 1D | | | | | | | | |
| 1E | | | | | | | | |
| 1F | 212 32<br>253 37 | 178 27<br>227 33 | | | | | | |
| 1G | 225 40<br>265 46 | | 30<br>355 24 | | 58 25<br>213 27 | | | |
| 1H | 132 39<br>295 42 | | | 52 27<br>242 29 | 195 35<br>215 41 | 190 29<br>218 32 | 137 27<br>215 34 | |
| 1I | 191 37<br>345 42 | | | 121 27<br>256 33 | 195 39<br>208 48 | 217 31<br>208 40 | 237 33<br>208 44 | 152 32<br>53 41 |
| 1J | 202 30<br>26 36 | | | 70 25<br>271 31 | 234 40<br>213 49 | 271 37<br>216 45 | 206 31<br>217 40 | 64 25<br>61 28 |
| 1K | 194 30<br>26 37 | | | 259 30<br>285 39 | 203 49<br>227 56 | 285 41<br>231 55 | 226 34<br>191 51 | 125 16<br>40 |
| 1L | 198<br>20 31 | | | 205 32<br>292 38 | 225<br>228 60 | 282 53<br>334 62 | 546 42<br>190 61 | |
| 1M | | | | 321 36<br>303 49 | 182 51<br>118 59 | 283 39<br>105 49 | 242 43<br>112 51 | |
| 1N | 133 27<br>31 31 | | | 180 42<br>293 49 | 170 40<br>113 49 | 223 36<br>84 44 | 206 34<br>108 43 | |
| 1O | 172 30<br>30 37 | 369 41<br>89 50 | | 337 31<br>248 40 | 218 39<br>152 49 | 250 36<br>127 43 | 291 31<br>145 41 | 140 27<br>27 31 |
| 1P | 228 30<br>44 34 | | | 280 35<br>259 43 | 218 37<br>185 47 | 256 31<br>174 40 | 294 34<br>175 47 | 219 29<br>32 37 |
| 1Q | 208 32<br>45 38 | | | 267 35<br>271 43 | 197 41<br>241 52 | 295 38<br>208 47 | 363 32<br>192 43 | 160 17<br>28 24 |
| 1R | | | | 153 27<br>289 34 | 149 55<br>232 62 | 186 51<br>264 57 | 297 43<br>198 60 | |
| 1S | | 526 26<br>70 37 | | 235 29<br>291 38 | 187 47<br>282 56 | 264 35<br>338 45 | 207 49<br>284 60 | |
| 1T | | | | 134 21<br>301 27 | 161 44<br>328 53 | 262 33<br>355 44 | 241 47<br>334 53 | |
| 1U | | | | | 226 32<br>337 41 | 154 26<br>15 28 | 212 37<br>0 43 | |
| 1V | | | | | 146 32<br>5 42 | 188 28<br>19 34 | 195 27<br>9 34 | |
| 1W | | 360 20<br>26 29 | | | 41 18<br>0 20 | | 24 22<br>13 26 | |
| 1X | | | | | | | | |

23 May 1979 Jacksonville Area Flight of the AMF (Inland, South, 10,000 Ft)

Quantity Plotted Above:

TABLE 4A (p. 4)

| INT/MIN | AVE.P |
|---|---|
| AOA | PK.P |

(Powers: dBm at Bottom Ant + 97)

| NU | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 |
|---|---|---|---|---|---|---|---|---|
| NAME | CecilNAS | Not | DaytonaB | TallaASR | MaconASR | AstorPk | PatrckAR | PatrckAS |
| PRI | 2663-4 | Used | 2559.7 | 2498.5 | 2500.8 | 2275 ±7 | 2276 ±7 | 3342 |
| PRF | 375.4 | | 390.7 | 400.2 | 399.9 | 439.5 | 360.2 | 299.2 |
| MODES | AAC | | AAC | AAC | AAC | AC | 2ACA/4 | AC |
| SCAN | 3.92 | | 3.92 | 3.92 | 4.68 | 2.80 | 12.01 | 3.92 |
| STAG | 1 | | 1 | 1 | 1 | Rm | 5 | 1 |
| 1A | | | | | | | | |
| 1B | | | | | | | | |
| 1C | | | | | | | | |
| 1D | | | | | | | | |
| 1E | | | | | | | | |
| 1F | | | | | | | | |
| 1G | | | | | | | | |
| 1H | | | | | | | | |
| 1I | | | | | | | | |
| 1J | 145 27 / 212 31 | | | | | | | |
| 1K | 203 31 / 239 37 | | 88 25 / 177 27 | | | | | |
| 1L | 306 37 / 206 44 | | 264 25 / 150 34 | | | | | |
| 1M | 273 32 / 149 42 | | 72 19 / 165 26 | 181 29 / 268 34 | | | | |
| 1N | 170 20 / 125 30 | | | 137 21 / 261 27 | 23 22 / 338 24 | | | |
| 1O | 224 23 / 149 28 | | | | 176 21 / 315 27 | | | |
| 1P | 179 27 / 178 31 | | | | | | | |
| 1Q | 186 30 / 211 35 | | 23 23 / 175 25 | | | | | |
| 1R | 216 35 / 228 47 | | 120 25 / 173 29 | | | | | |
| 1S | 273 33 / 305 41 | | 214 32 / 155 38 | | | 198 27 / 195 28 | 187 29 / 181 33 | 141 29 / 159 34 |
| 1T | 131 30 / 314 38 | | 247 34 / 175 40 | | | 266 31 / 213 37 | 162 33 / 177 40 | 164 31 / 174 39 |
| 1U | 220 27 / 333 31 | | 314 52 / 167 60 | | | 502 35 / 257 42 | 211 34 / 164 43 | 156 31 / 166 38 |
| 1V | 96 19 / 0 22 | | 248 42 / 16 51 | | | 372 26 / 294 30 | 301 39 / 172 51 | 171 34 / 172 43 |
| 1W | | | 246 31 / 22 37 | | | 146 22 / 339 25 | 282 52 / 152 64 | 221 48 / 152 58 |
| 1X | | | | | | | 322 44 / 9 59 | 312 35 / 8 51 |

23 May 1979 Jacksonville Area Flight of the AMF (Inland, South, 10,000 Ft)

Quantity Plotted Above:

TABLE 4A (p. 5)

| INT/MIN | AVE.P |
|---|---|
| AOA | PK.P |

(Powers: dBm at Bottom Ant 97)

| NO | 41 | 42 | 43 | 44 | 45 | 46 | 51 | 52 |
|---|---|---|---|---|---|---|---|---|
| NAME | OrlndoAS | TampaASR | DaytRamp | McDillAR | SarasoAS | WPalmBAS | McDill | McDill |
| PRI | 2626 | 2884 | 3064-5 | 4147 | 2564 | 3049 | 4000 | 3991 ave |
| PRF | 380.7 | 346.7 | 326.3 | 241.1 | 389.9 | 327.9 | 250.0 | 250.6 |
| MODES | AAC | AAC | A | 2ACA | AAC | AAC | 2*AC | AC |
| SCAN | 4.71 | 4.70 | 2.18 | 11.98 | 4.04 | 4.71 | 9.32 | 4.70 |
| STAG | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 3 |
| 1A | | | | | | | | |
| 1B | | | | | | | | |
| 1C | | | | | | | | |
| 1D | | | | | | | | |
| 1E | | | | | | | | |
| 1F | | | | | | | | |
| 1G | | | | | | | | |
| 1H | | | | | | | | |
| 1I | | | | | | | | |
| 1J | | | | | | | | |
| 1K | | | | | | | | |
| 1L | | | | | | | | |
| 1M | | | | | | | | |
| 1N | | | | | | | | |
| 1O | | | | | | | | |
| 1P | | | | | | | | |
| 1Q | | | | | | | | |
| 1R | | | | | | | | |
| 1S | | | | | | | | |
| 1T | 194 31 / 190 37 | | | | | | | |
| 1U | 224 38 / 202 42 | 127 26 / 242 30 | 280 25 / 162 29 | 107 36 / 218 43 | | | 50 23 / 224 25 | 108 27 / 222 31 |
| 1V | 230 42 / 245 48 | 121 26 / 252 32 | | 71 35 / 238 41 | | | | 144 30 / 242 37 |
| 1W | 274 43 / 305 50 | 232 32 / 253 40 | | 96 41 / 247 47 | 50 24 / 243 26 | 68 24 / 155 38 | 236 33 / 248 36 | 122 33 / 247 38 |
| 1X | 236 42 / 312 49 | | | | | 68 24 / 148 28 | | |

23 May 1979 Jacksonville Area Flight of the AMF (Inland, South, 10,000 Ft)

Quantity Plotted Above:

TABLE 4A (p. 6)

| INT/MIN | AVE.P |
|---|---|
| AOA | PK.P |

(Powers: dBm at Bottom Ant 97)

| NO | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| NAME | AirbNr2Y | Pope AFB | BogueMCA | BensonAR | MyrtleAF | Near 2Y | JacksvNC | FaytvASR |
| PRI | 3335 | 3654 | 2676 | 2700 ±7 | 4000- | 3991 ave | 2530 | 2625 |
| PRF | 299.8 | 273.6 | 373.6 | 370.3 | 250.0 | 250.6 | 395.2 | 380.9 |
| MODES | 2*AC | AAC | AC | AC | 1AC | AC | A | AAC |
| SCAN | 3.86 | 3.85 | 3.91 | 10.12 | 9.31 | 4.68 | 4.04 | 3.92 |
| STAG | 1 | 1 | 1 | 5 | 1 | 3 | 1 | 1 |
| | | | | | | | | |
| 2A | | | | | | | | |
| 2C | | | | | | | | |
| 2E | | | | | | | | |
| 2G | | | | | | | | |
| 2I | | | | | | | | |
| 2K | | | | | | | | |
| 2M | | | | | | | | |
| 2O | | | | | | | | |
| 2Q | | | | | | | | |
| 2S | | | | | | | | |
| 2U | | | | 65  23<br>355 29 | | | 123  28<br>353 34 | 35  25<br>355 27 |
| 2W | 123  28<br>22 30 | | 221  32<br>55 37 | 201  30<br>3 36 | | 25<br>292 35 | 224  33<br>10 42 | 138  27<br>346 30 |
| 2Y | 220  37<br>49 42 | 186  32<br>308 36 | 248  34<br>49 43 | 195  39<br>332 44 | | 221<br>223 44 | 448  34<br>106 51 | 263  36<br>299 42 |

23 May 1979 Jacksonville Area Flight of the AMF (Ocean Leg, North, 25,000 Ft.)

Quantity Plotted Above:

| INT/MIN | AVE.P |
|---|---|
| AOA | PK.P |

TABLE 4B (p. 1)

(Powers: dBm at Bottom Ant + 97)

| NO | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|
| NAME | MyrtleAF | Shaw AFB | ColASR-7 | CharlsAS | JedbrgAR | NoCharls | FtFisher | NrCharls |
| PRI | 3331 | 3328(9) | 2245 av | 2566 | 2901 ±7 | 3040 | 4146 | 2458 ±1 |
| PRF | 300.2 | 300.4 | 445.4 | 389.6 | 344.7 | 328.9 | 241.2 | 406.8 |
| MODES | AC | AC | AAC | A | AC | 2ACA/4 | 2ACA/4 | 2 |
| SCAN | 4.67 | 3.92 | 4.67 | 4.70 | 12.02 | 11.75 | 11.98 | 3.92 |
| STAG | 1 | 1 | 8 | 1 | 5 | 1 | 1 | 1 |
| | | | | | | | | |
| 2A | | | | | | | | |
| 2C | | | | | | | | |
| 2E | | | | | | 49 24<br>9 28 | | |
| 2G | | | | | | 165 31<br>341 36 | | |
| 2I | | | | 34 22<br>345 | 187 27<br>343 | 205 30<br>347 | 128 23<br>10 | |
| 2K | | | | 140 20<br>4 | 200 28<br>22 | 307 28<br>2 | 70 14<br>21 | |
| 2M | | | | 236 21<br>34 | 100 23<br>28 | 339 28<br>30 | | |
| 2O | | | | 88 23<br>27 | 95 26<br>17 | 197 28<br>26 | | |
| 2Q | | | | 75 20<br>7 | 141 22<br>349 | 200 28<br>7 | 52 23<br>24 | |
| 2S | | | | 154 25<br>342 33 | 129 27<br>341 33 | 285 32<br>338 44 | | |
| 2U | | 60 25<br>328 28 | | 181 27<br>296 31 | 181 31<br>301 36 | 288 34<br>297 43 | 215 37<br>357 45 | |
| 2W | | | 240 29<br>298 35 | 224 22<br>278 28 | 219 26<br>275 34 | 388 27<br>278 39 | 241 45<br>16 55 | |
| 2Y | | 80 23<br>240 35 | | | 116 24<br>221 28 | 282 34<br>224 43 | 290 40<br>138 55 | |

23 May 1979 Jacksonville Area Flight of the AMF (Ocean Leg, North, 25,000 Ft.)

Quantity Plotted Above:

| INT/MIN | AVE.P |
|---|---|
| AOA | PK.P |

TABLE 4B (p. 2)                    (Powers: dBm at Bottom Ant + 97)

| NO | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|
| NAME | Aiken AR | BeauftMC | BeauftMC | ShipNr2K | AugustAS | ShipNr2K | Statesbo | JacksvNAS |
| PRI | 4135 | 3251(2) | 4588 ave | 3133±150 | 2531 | 3415 ave | 2440-1 | 2819 |
| PRF | 241.8 | 307.5 | 218.0 | 319 ± | 395.0 | 292.8 | 409.7 | 354.7 |
| MODES | AC | 12AC | 2*12AC | 4*12AC | AAC | 4*12AC | 1 | 2ACA/4 |
| SCAN | 12.04 | 9.82 | 9.59 | 3.82 | 3.92 | 7.85 | 8.83 | 12.02 |
| STAG | 1 | 1 | 12 | Rm | 1 | 9 | 1 | 1 |
| | | | | | | | | |
| 2A | | | | | | 528  23<br>16 27 | | |
| 2C | | | | | | 222  26<br>347 30 | | 191  28<br>311 36 |
| 2E | | | | | | 498  30<br>341 38 | | 392  33<br>292 42 |
| 2G | | | | | | 789  34<br>315 42 | | 360  31<br>283 41 |
| 2I | | | 405  30<br>321 37 | | | 671  39<br>279 47 | | 312  34<br>282 |
| 2K | | | 280  26<br>332 | | | 425  53<br>34 60 | | 404  43<br>262 52 |
| 2M | 85  28<br>341 | | 337  23<br>0 | | | 447  39<br>98 45 | | 364  51<br>247 61 |
| 2O | 38  24<br>357 | | 440  27<br>26 | | | 576  44<br>77 53 | 49  17<br>0 | 351  47<br>261 59 |
| 2Q | | | 302  21<br>343 | 1200<br>295 44 | | 60  29<br>290 34 | | 356  34<br>287 43 |
| 2S | | | 178  25<br>299 27 | 1260<br>270 38 | | 980  30<br>271 43 | 80  24<br>305 27 | 256  31<br>280 44 |
| 2U | 75  28<br>300 33 | | 50  24<br>274 26 | | | 660  29<br>252 38 | | 173  19<br>242 24 |
| 2W | 79  30<br>292 35 | | 153  18<br>263 22 | | | 613  24<br>217 30 | | |
| 2Y | | | | | | | | |

23 May 1979 Jacksonville Area Flight of the AMF (Ocean Leg, North, 25,000 Ft.)

Quantity Plotted Above:

| INT/MIN | AVE.P |
|---|---|
| AOA | PK.P |

TABLE 4B (p. 3)                              (Powers: dBm at Bottom Ant + 97)

| NO | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 |
|---|---|---|---|---|---|---|---|---|
| NAME | SavnnhAS | ShipNr2K | AWACS | ValdosAR | WhitehAR | JackInAS | JacksNAS | BeauftMC |
| PRI | 3095 ±7 | 4048-9 | 5005-74 | 2700- | 2741 ±7 | 2969 ±7 | 3461 | 2594 |
| PRF | 323.1 | 247.0 | 200- | 370.3 | 364.8 | 336.8 | 288.9 | 385.4 |
| MODES | A | 4*12AC | 2AC | AC | AAC | AAC | 2AC | 2/AC |
| SCAN | 4.70 | 7.90 | | 11.98 | 12.02 | 4.70 | 3.92 | 3.93 |
| STAG | 5 | 1 | Rm | 1 | 5 | 5 | 1 | 1 |
| 2A | | | | | | | | |
| 2C | | | | | | | | |
| 2E | | | | | 185 29 / 290 36 | 160 21 / 305 27 | 145 23 / 294 34 | |
| 2G | | | | | 102 30 / 288 37 | 167 28 / 297 33 | 88 34 / 282 38 | |
| 2I | | | | | 150 37 / 283 | 200 31 / 275 | 216 30 / 279 | 183 31 / 3 21 |
| 2K | | | | 31 28 / 304 | 179 39 / 265 48 | 187 32 / 267 | 265 36 / 260 | 215 29 / 333 |
| 2M | 154 25 / 358 | | | 202 33 / 311 | 214 46 / 269 53 | 272 42 / 270 51 | 256 45 / 247 53 | 196 24 / 359 |
| 2O | 152 20 / 9 | | | 150 28 / 293 | 190 41 / 263 | 253 37 / 300 46 | 450 34 / 252 52 | 210 26 / 26 |
| 2Q | 205 23 / 335 | | | | 172 33 / 286 | 162 28 / 290 | 289 33 / 288 42 | 204 22 / 344 |
| 2S | | | | | 176 27 / 272 34 | 134 20 / 276 27 | 170 23 / 274 33 | 84 24 / 299 28 |
| 2U | 35 / 280 27 | | | | | | | 191 27 / 276 33 |
| 2W | | | | | | | | 212 24 / 263 29 |
| 2Y | | | | | | | | |

23 May 1979 Jacksonville Area Flight of the AMF (Ocean Leg, North, 25,000 Ft.)

Quantity Plotted Above:

| INT/MIN | AVE.P |
|---|---|
| AOA | PK.P |

TABLE 4B (p. 4)

(Powers: dBm at Bottom Ant + 97)

35

| NO | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 |
|---|---|---|---|---|---|---|---|---|
| NAME | CecilNAS | Not | DaytonaB | TallaASR | MaconASR | AstorPk | PatrckAR | PatrckAS |
| PRI | 2663-4 | Used | 2559.7 | 2498.5 | 2500.8 | 2275 ±7 | 2776 ±7 | 3342 |
| PRF | 375.4 | | 390.7 | 400.2 | 399.9 | 439.5 | 360.2 | 299.2 |
| MODES | AAC | | AAC | AAC | AAC | AC | 2ACA/4 | AC |
| SCAN | 3.92 | | 3.92 | 3.92 | 4.68 | 2.80 | 12.01 | 3.92 |
| STAG | 1 | | 1 | 1 | 1 | Rm | 5 | 1 |
| | | | | | | | | |
| 2A | | | | | | | 215 32 / 318 42 | 248 28 / 315 41 |
| 2C | | | 131 26 / 300 33 | | | | 268 28 / 275 43 | 198 23 / 280 37 |
| 2E | | | 201 16 / 275 24 | | | | 224 35 / 246 45 | 158 24 / 244 34 |
| 2G | | | | | | | 198 20 / 233 29 | 175 22 / 234 29 |
| 2I | | | 92 25 / 251 | | | | 131 30 / 196 | 117 28 / 194 |
| 2K | | | 128 24 / 225 | | | | 152 32 / 186 | 170 29 / 185 |
| 2M | 210 30 / 256 | | 193 26 / 197 | 142 27 / 267 35 | 206 31 / 305 36 | 310 26 / 190 | 202 27 / 179 | 173 28 / 179 |
| 2O | 209 31 / 252 | | 181 27 / 178 | 162 19 / 290 37 | | 99 22 / 191 | 172 30 / 176 | 119 28 / 178 |
| 2Q | 289 33 / 288 42 | | 165 23 / 205 | | | | 189 29 / 221 | 137 24 / 220 |
| 2S | | | 182 24 / 226 29 | | | | 110 16 / 225 23 | |
| 2U | | | | | | | 68 / 200 26 | 51 24 / 317 27 |
| 2W | | | | | | | | |
| 2Y | | | | | | | | |

23 May 1979 Jacksonville Area Flight of the AMF (Ocean Leg, North, 25,000 Ft.)

Quantity Plotted Above:

| INT/MIN | AVE.P |
|---|---|
| AOA | PK.P |

TABLE 4B (p. 5)

(Powers: dBm at Bottom Ant + 97)

36

| NO | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 |
|---|---|---|---|---|---|---|---|---|
| NAME | OrlndoAS | TampaASR | DaytRamp | McDillAR | SarasoAS | WPalmBAS | RichmdAR | ShipNr2K |
| PRI | 2626 | 2884 | 3064-5 | 4147 | 2564 | 3049 | 2820.0 | 3052-61 |
| PRF | 380.7 | 346.7 | 326.3 | 241.1 | 389.9 | 327.9 | 354.6 | 327 ± |
| MODES | AAC | AAC | A | 2ACA | AAC | AAC | 2ACA/4 | 4*12AC |
| SCAN | 4.71 | 4.70 | 2.18 | 11.98 | 4.04 | 4.71 | 10.11 | 3.80 |
| STAG | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | | | | | | | | |
| 2A | 169 21 / 290 26 | | | | | 186 29 / 206 37 | | |
| 2C | 242 28 / 295 36 | | | 21 14 / 282 19 | | 66 12 / 221 17 | 56 14 / 209 19 | |
| 2E | 217 25 / 284 30 | | | | | 153 23 / 202 33 | | 739 25 / 341 35 |
| 2G | | | | | | | | 660 33 / 317 42 |
| 2I | | | | | | | | 696 41 / 280 49 |
| 2K | 184 29 / 208 | | | | | | | 575 50 / 36 61 |
| 2M | 156 27 / 193 | 158 26 / 190 | | 56 27 / 187 | | | | 631 39 / 100 |
| 2O | 189 29 / 191 | 149 22 / 217 | | 112 26 / 202 32 | | | | 864 42 / 77 51 |
| 2Q | 134 16 / 201 | | | | | | | |
| 2S | | | | | | | | |
| 2U | | | | | | | | |
| 2W | | | | | | | | |
| 2Y | | | | | | | | |

23 May 1979 Jacksonville Area Flight of the AMF (Ocean Leg, North, 25,000 Ft.)

Quantity Plotted Above:

| INT/MIN | AVE.P |
|---|---|
| AOA | PK.P |

TABLE 4B (p. 6)  (Powers: dBm at Bottom Ant + 97)

37

| NO | 49 | 50 | 51 | 52 | 53 | 54 | 55 | 56 |
|---|---|---|---|---|---|---|---|---|
| NAME | MayportN | Not | McDill | McDill | Not | ShipNr2K | NrMyrtle | BogueMCA |
| PRI | 1522±4 | Used | 4000 | 3991 ave | Used | 4129-30 | 912 | 7506.4 |
| PRF | 657 | | 250.0 | 250.6 | | 242.1 | 1096 | 133.2 |
| MODES | A/1/2 | | 2*AC | AC | | 4*12AC | A | A |
| SCAN | 7.18 | | 9.32 | 4.70 | | 7.90 | 3.94 | 6.37 |
| STAG | Rm | | 1 | 3 | | 1 | 1 | 1 |
| 2A | | | | | | | | |
| 2C | | | | | | | | |
| 2E | | | | | | | | |
| 2G | | | | | | | | |
| 2I | | | | | | | | |
| 2K | | | | | | | | |
| 2M | 400  32<br>249 40 | | 141  25<br>188 | 75  26<br>181 | | | | |
| 20 | | | 58  20<br>201 23 | 50<br>205 27 | | | | |
| 2Q | | | | | | | | |
| 2S | | | | | | 1024  26<br>272 42 | | |
| 2U | | | | | | 314  22<br>251 27 | 750  24<br>317 31 | 40<br>40 27 |
| 2W | | | | | | 486  25<br>216 34 | 1252  33<br>299 39 | 120<br>55 31 |
| 2Y | | | | | | | | |

23 May 1979 Jacksonville Area Flight of the AMF (Ocean Leg, North, 25,000 Ft.)

Quantity Plotted Above:

TABLE 4B  (p. 7)

| INT/MIN | AVE.P |
|---|---|
| AOA | PK.P |

(Powers: dBm at Bottom Ant + 97)

| NO | 57 | 58 | 59 | 60 | 61 | 62 | | |
|---|---|---|---|---|---|---|---|---|
| NAME | NrSeyJoh | CharltAS | MaidenAR | PanamaAR | W.of 2M+ | S.of 2M+ | | |
| PRI | 3991 ave | 2626.8 | 2778±7 | 2818±7 | 3502-3 | 3650 | | |
| PRF | 250.6 | 380.7 | 359.9 | 354.9 | 285.5 | 273.9 | | |
| MODES | AC | AAC | AC | 2ACA | AC | AC | | |
| SCAN | 4.68 | 4.70 | 12.02 | 12.02 | 3.94 | 3.85 | | |
| STAG | 3 | 1 | 5 | 5 | 1 | 1 | | |
| 2A | | | | | | | | |
| 2C | | | | | | | | |
| 2E | | | | | | | | |
| 2G | | | | | | | | |
| 2I | | | | | | | | |
| 2K | | | | | | | | |
| 2M | | | | | | | | |
| 2O | | | | | | | | |
| 2Q | | | | | | | | |
| 2S | | | | | | | | |
| 2U | 120  31<br>347 36 | | | | | | | |
| 2W | 140<br>18 33 | 65  24<br>312 29 | | | | | | |
| 2Y | 168<br>40 40 | | 112  26<br>320 29 | | | | | |

23 May 1979 Jacksonville Area Flight of the AMF (Ocean Leg, North, 25,000 Ft.)

Quantity Plotted Above:

| INT/MIN | AVE.P |
|---|---|
| AOA | PK.P |

TABLE 4B (p. 8)

(Powers: dBm at Bottom Ant ∤ 97)

### 3.4.1 Master List Organization

Each column of these tables corresponds to one of the 59 interrogators; each row is headed by a location code: a letter of the alphabet, preceded by "1" for the first, and by "2" for the second leg of the flight. For Table 4A, dealing with the first leg, these are 1A, 1B, 1C,....., 1X. For Table 4B, dealing with the second leg, they are 2A, 2C, 2E, ....., 2Y (every other location only is included). As noted at the bottom of each page the four entries for each location/interrogation (column/row) intersection are:

```
┌─────────────────────┐
│  INT/MIN   AVE. P   │
│                     │
│       AOA   PK. P   │
└─────────────────────┘
```

### 3.5  PRI/PRF Distributions for Locations 1H, 1U, and 2M+ (Fig. 8)

Figure 8 presents three PRI/PRF distributions of the interrogations received in 1 minute from all interrogators visible at locations 1H, 2M+, and 1U. The distribution for location 2M+ is shown in the middle (Figure 8b), since this location is geographically between the other two, and since it has more than a dozen interrogators in common (mutually visible) with the other two (top and bottom) locations.

Interrogations marked by the numbers "8", "9", "3", and "12" show all the PRI received from the same four interrogators on staggered PRI. The corresponding interrogators are:

| | | | |
|---|---|---|---|
| 8: | 8-Pulse Stagger | No. 11 | Columbia ASR-7 |
| 9: | 9-Pulse Stagger | No. 22 | Shipborne Near 2K |
| 3: | 3-Pulse Stagger | No. 52 | Mac Dill AFB |
| 12: | 12-Pulse Stagger | No. 19 | Beaufort MCAS |

All of the PRI of the 9-Pulse-Stagger (P-S) and of the 3-P-S are within the range of the plots but one of the PRI of the 9-P-S (6810 µs) is off scale (see Figure 7). The 9-P-S (Int. 22) actually uses only 4 different PRI (2831, 3051, 3881, and 6810 µs), but it does not repeat these until 9 PRI later, which gives the 9-pulse stagger designation.

Similarly, Int. 19 (on 12-P-S) actually uses only 4 different PRI (3774, 4720, 6000 and 10362 µs, see Figure 7), but it does not repeat these until 12 PRI later (hence the designation: 12-pulse stagger). Note that only one of its PRI (3774 µs) is within the range of Figure 8, but that three-quarters of all interrogations are received on this single PRI.

Table 5 gives a list of shared and un-shared interrogators among the three PRI/PRF distributions of Figure 8. From the table, 5 are common to all three parts, 13 to parts (a) and (b), 14 to parts (b) and (c), and the rest are un-shared. Interrogators seen at locations 1H and 1U may easily be found from the visibility matrix (left half) of Figure 6. Note that Table 5 gives a list of interrogators seen at loc. 2M+ (a location not included in other figures or tables).
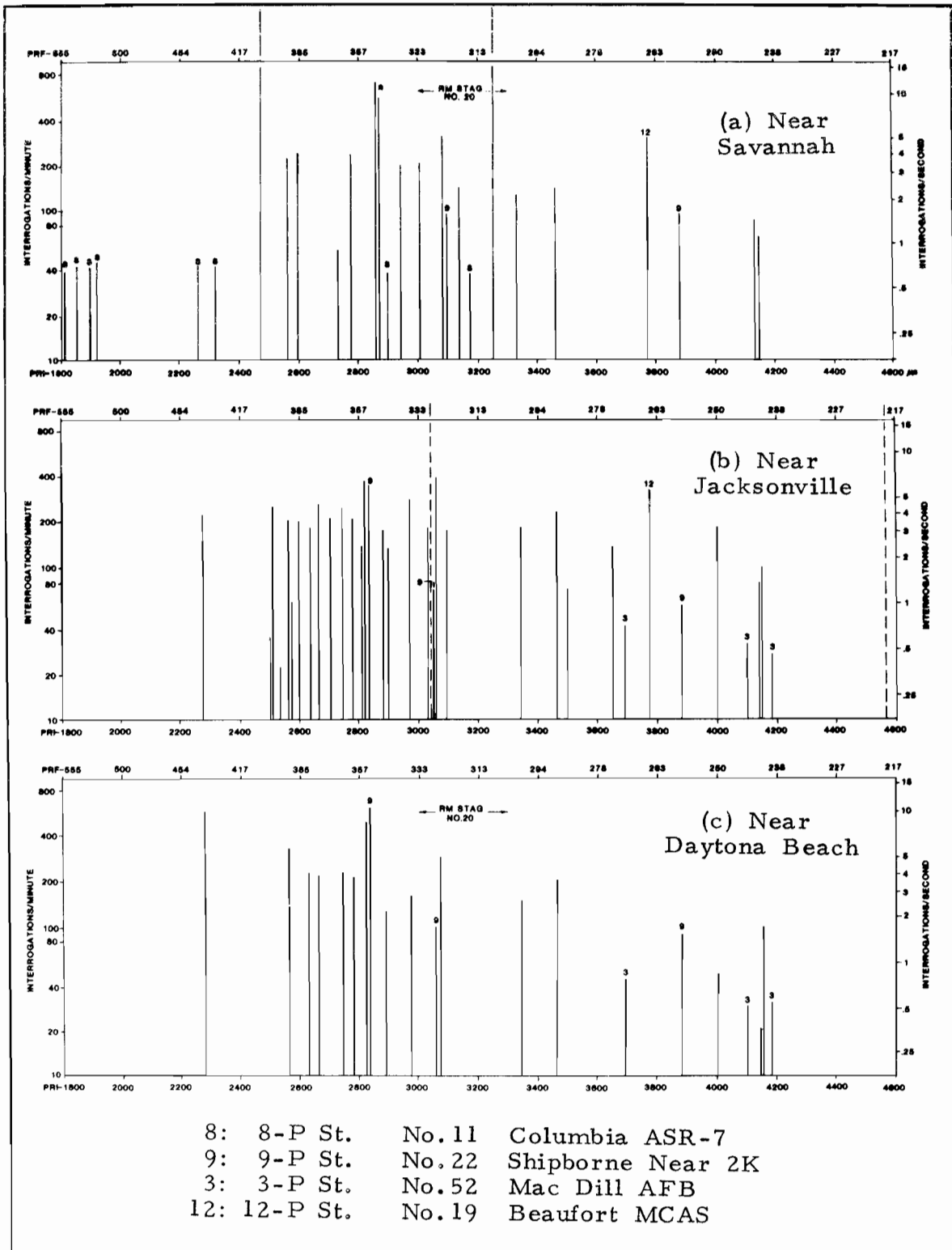
Three PRI/PRF Distributions (Near Savannah,
Jacksonville And Daytona Beach), Plotted from
60-Second Recordings on 23 May 1979 by the AMF
Figure 8

TABLE   5

SHARED AND UN-SHARED INTERROGATORS
IN THE THREE DISTRIBUTIONS OF FIGURE 8

(1)   Interrogators Common to the Three Locations

PRI

| No. 29 | . Whitehouse ARSR | 2741 µs |
| No. 24 | Jacksonville NAS | 2819 µs |
| No. 30 | Jacksonville Intnl | 2969 µs |
| No. 22 | Shipborne Near 2K | 3415 µs (ave. 9-P-S) |
| No. 31 | Jacksonville NAS | 3461 µs |

(2)   Interrogators Common to Locations 1H, and 2M+

PRI

| No. 21 | Augusta ASR | 2531 µs |
| No. 12 | Charleston ASR | 2566 µs |
| No. 28 | Valdosta ARSR | 2700 µs |
| No. 29 | Whitehouse ARSR | 2741 µs |
| No. 24 | Jacksonville NAS | 2819 µs |
| No. 13 | Jedburg ARSR | 2901 µs |
| No. 30 | Jacksonville Intnl | 2969 µs |
| No. 14 | No. Charleston | 3040 µs |
| No. 25 | Savannah ASR | 3095 µs |
| No. 22 | Shipborne Near 2K | 3415 µs (ave. 9-P-S) |
| No. 31 | Jacksonville NAS | 3461 µs |
| No. 17 | Aiken AFS ARSR | 4135 µs |
| No. 19 | Beaufort MCAS | 4588 µs (ave. 12-P-S) |

(3)   Interrogators Common to Locations 2M+ and 1U

PRI

| No. 38 | Astor Park | 2275 µs |
| No. 35 | Daytona Beach ASR | 2559 µs |
| No. 41 | Orlando ASR | 2626 µs |
| No. 33 | Cecil Fld NAS | 2663 µs |
| No. 29 | Whitehouse ARSR | 2741 µs |
| No. 39 | Patrick AFB ARSR | 2776 µs |
| No. 24 | Jacksonville NAS | 2819 µs |
| No. 42 | Tampa ASR | 2884 µs |
| No. 30 | Jacksonville Intnl | 2969 µs |

42

TABLE 5 (Continued)

|        |        |                     | PRI                        |
|--------|--------|---------------------|----------------------------|
| No. 40 |        | Patrick AFB ASR     | 3342 µs                    |
| No. 22 |        | Shipborne Near 2K   | 3415 µs (ave. 9-P-S)       |
| No. 31 |        | Jacksonville NAS    | 3461 µs                    |
|        |        |                     |                            |
| No. 52 |        | Mac Dill AFB        | 3991 µs (ave. 3-P-S)       |
| No. 44 |        | Mac Dill AFB ARSR   | 4147 µs                    |

(4)  Unshared Interrogators at Locations 1H, 1U, and 2M+

    (a)  Interrogators seen at 1H, but not at 2M+ (with the 13 shared ones, they make up the 19 seen at 1H)

|        |        |                     | PRI                        |
|--------|--------|---------------------|----------------------------|
| No. 11 |        | Columbia ASR-7      | 2245 µs (ave. 8-P-S)       |
| No. 23 |        | Statesboro          | 2440 µs                    |
| No. 20 |        | Shipborne Near 2K   | 3133 µs (ave. Random)      |
|        |        |                     |                            |
| No. 18 |        | Beaufort MCAS       | 3251 µs                    |
| No. 10 |        | Shaw AFB            | 3328 µs                    |
| No. 15 |        | Ft. Fisher          | 4146 µs                    |

    (b)  Interrogators seen at 2M+, but not at 1H (with the 13 shared ones, they make up the 31 seen at 2M+)

|        |        |                     | PRI                         |
|--------|--------|---------------------|-----------------------------|
| No. 49 |        | Mayport NS          | 1522 µs (2nd + 3rd Harm's)  |
| No. 38 |        | Astor Park          | 2275 µs (ave. Rm)           |
| No. 36 |        | Tallahassee ASR     | 2498 µs                     |
|        |        |                     |                             |
| No. 37 |        | Macon ASR (Robins)  | 2500 µs                     |
| No. 35 |        | Daytona Beach ASR   | 2559 µs                     |
| No. 32 |        | Beaufort MCAS       | 2594 µs                     |
|        |        |                     |                             |
| No. 41 |        | Orlando ASR         | 2626 µs                     |
| No. 33 |        | Cecil Fld NAS       | 2663 µs                     |
| No. 39 |        | Patrick AFB ARSR    | 2776 µs                     |
|        |        |                     |                             |
| No. 60 |        | Panama City ARSR    | 2818 µs                     |
| No. 42 |        | Tampa ASR           | 2884 µs                     |
| No. 48 |        | Shipborne Near 2K   | 3060 µs                     |

TABLE 5 (Continued)

|          |                     | PRI                      |
|----------|---------------------|--------------------------|
| No. 40   | Patrick AFB ASR     | 3342 µs                  |
| No. 61   | West of Loc. 2M+    | 3502 µs                  |
| No. 62   | South of Loc. 2M+   | 3650 µs                  |
|          |                     |                          |
| No. 52   | Mac Dill AFB        | 3991 µs (ave. 3-P-S)     |
| No. 51   | Mac Dill AFB        | 4000 µs                  |
| No. 44   | Mac Dill ARSR       | 4147 µs                  |

(c) <u>Interrogators seen at 1U, but not at 2M+</u> (with the 14 shared ones, they make up the 18 seen at location 1U)

|          |                     | PRI                      |
|----------|---------------------|--------------------------|
| No. 43   | Daytona Ramp Tester | 3064 µs                  |
| No. 20   | Shipborne Near 2K   | 3133 µs (ave. Random)    |
|          |                     |                          |
| No. 51   | Mac Dill AFB        | 4000 µs                  |
| No. 15   | Ft. Fisher          | 4146 µs                  |

### 3.5.1  PRI/PRF Distributions

#### (1)  Distribution at 1H (Figure 8a)

Even though most of the interrogations fall into a third of the range shown (2440 to 3460 μs), all PRI are in the "clear" (they do not overlap each other).  The main  reason for this is the  small number of interrogators seen at  location 1H (18 in all).   Even the Columbia ASR-7 on 8-pulse stagger dovetails with  the rest  of the interrogators.   Its PRI  (shown in Figure 7) indicate the use of a so-called P-Crystal.

#### (2)  Distribution at 2M+ (Figure 8b)*

As might be  expected, the distribution at location  2M+, where the transmissions from 31 interrogators were heard, has a number  of problems. Tallahassee  (on 2498.5 μs) is surrounded  by Macon  ASR on (2500.8  μs) which uses 5-pulse stagger here. Jacksonville NAS (Int. 24 on 2819 μs)  is similarly surrounded by  Panama City ARSR (Int. 60  on 2818 μs) which also  uses 5-pulse stagger.

The  second harmonic  of Mayport NS  (Int. 49  on 1552 $\pm$  4 μs) extends  from 3055  to 3050  μs.  This  range  of random  PRI surrounds  No. Charleston  (Int. 14 on 3040 PRI).   It is also within 1 μs of  one of the PRI received  on  9-pulse stagger (3051 μs),  and  is within  3 μs  of  Int.  48 (Shipborne near 2K) which is coming in on 3053  μs here, about 7 μs  below its highest PRI observed elsewhere.

Some near coincidences, which cause no problem, are the Daytona Beach/Charleston ASR's and  the  Aiken AFS/Mac  Dill AFB  ARSR's.   The  PRI differences involved here are  6 and 12 μs, respectively.   The third harmonic of Mayport (4546 to 4571 μs) is also all in the clear.

#### (3)  Distribution at 1U (Figure 8c)

The small number of interrogators (19) observed here  make this distribution very  similar  to the  one at  1H.  With  the  exception of  the interrogations from  Ft. Fisher and Mac Dill  ARSR (which  are within 1  μs of each other), all interrogations are in the clear.

_____  *Note that Section 7.2.5 contains a thorough  discussion of synchronous interference observed during the Jacksonville flight.

## 3.6 Reflections Observed (Table 6)

Reflections observed during the flight are listed in Table 6 with the following data:

- Location where reflection was seen;
- Interrogator number;
- Name of interrogator responsible for the refelctions;
- Number of reflections per scan;
- Reflection delays (µs);
- Peak-to-peak loss (dB) with respect to mainbeam;
- Estimated distance from antenna to reflector surface (ft);
- Estimated azimuth of reflector (deg); and
- Angular location of reflections from the mainbeam (deg).

The reflections listed come from four military interrogators which probably use regular SLS. The latter is deduced since the use of ISLS (improved SLS) would probably suppress the reflections, and because the use of no SLS would probably yield much higher interrogation rates in the vicinity of these interrogators.

Interesting reflections occur at location 1Q. The 4.5-µs reflections from interrogator 31 at Jacksonville NAS have sometimes almost no loss associated with them --a highly unusual situation. The fact that the peak power received from interrogator 31 at location 10 is about 10 dB lower (at -54 dBm) than expected, compared to the power received at neighboring locations (see page 4 of Table 4A), suggests that the direct interrogations undergo distructive interference, while the reflected signals (over a slightly different path) are reinforced (arrive in-phase).

## 3.7 Mode 4 Interrogations Observed (Table 7)

Mode 4 interrogations observed during the flight are listed in Table 7. Each line of the table contains the following information:

- Location where Mode 4 was observed;
- Number of interrogator responsible;
- Name of interrogator responsible for Mode 4;
- Duration of Mode 4 (sec);
- Angular location of Mode 4 in scan w. resp. to mainbeam (deg);
- Distance of interrogator transmitting Mode 4 from the AMF (nmi).

The table shows 15 occurrences of Mode 4 interrogations at a dozen different locations (two separate cases occur at locations 1I, 1K and 2A). The 5 interrogators responsible for Mode 4 are Ft. Fisher, Jacksonville NAS (number 24), Patrick ARSR, Richmond ARSR and No. Charleston.

TABLE  6.

REFLECTIONS OBSERVED

| Loc. | Interrogator | | Reflections | Delay | Loss | Reflector | | Loc. of |
| Code | No. | Name | per Scan | (µs) | (dB) | Dis(') | Az(°) | Refl. in Scan |
|---|---|---|---|---|---|---|---|---|
| 1A | 9 | Myrtle Beach | 15 18 17 15 <br> 18 18 | 1.8 | 18 | 900 | 250 | MB + 177 |
| 1B | " | " | 22 18 12 25 | 1.7 | 37 | 800 | 234 | MB + 170 |
| 1H | 24 | Jacksv.NAS | 38 38 36 | 9 | 15 | 9000 | 221 | MB + 163 |
| 1M | " | " | 29 39 40 46 | 3.8 | 29 | 2000 | 76 | MB + 121 |
| 1R | " | " | 19 24 18 8 | 1 | 30 | | | |
| 1T | " | " | 130 (total) | 1,3,4 | 32 | 3000 | 40 | MB − 112 |
| 10 | " | " | 15 | 1.3 | 20 | | 13 | MB + 43 |
| 1Q | 31 | Jacksv.NAS | 14 13 14 14 <br> 14 13 10 11 | 4.5 | 0.15 | 2200 | 150 | MB + 148 |
| 1R | " | " | 6 8 12 12 7 | 4.5 | 32 | 2200 | 157 | MB + 139 |
| 2Y | 14 | No. Charleston | 4 14 17 | 2.2 | 17 | 1100 | 70 | MB + 207 |

## TABLE 7.

### MODE 4 OBSERVED

| Loc. Code | Interrogator No. | Name | Length (sec) | Location in Scan | Approximate Distance (nmi) |
|---|---|---|---|---|---|
| 1B | 15 | Ft. Fisher | 0.10 | MB + 21 | 50 |
| 1I | 15 | Ft. Fisher | 0.08 | on MB | 215 |
| " | " | " | 0.22 | on MB | 215 |
| 1K | 24 | Jacksonville NAS | 0.09 | MB + 45 | 35 |
| " | " | " | 0.10 | MB + 68 | 35 |
| 1S | 24 | Jacksonville NAS | 0.30 | MB - 17 | 16 |
| 1T | 24 | Jacksonville NAS | 0.46 | MB - 22 | 36 |
| 1W | 39 | Patrick AFB ARSR | 0.25 | MB + 46 | 15 |
| 1W+ | 39 | Patrick AFB ARSR | 0.37 | MB + 167 | 5 |
| 1X | 39 | Patrick AFB ARSR | 0.13 | MB + 195 | 18 |
| 2A | 39 | Patrick AFB ARSR | 0.19 | on MB | 42 |
| " | " | " | 0.19 | on MB | 42 |
| 2C | 47 | Richmond AFS ARSR | 0.09 | on MB | 65 |
| 2D | 14 | No. Charleston | 0.20 | on MB | 250 |
| 2N+ | 24 | Jacksonville NAS | 0.40 | MB - 19 | 35 |

Observed durations vary from a low of 0.08 sec. to a high of 0.46 sec. Average duration is 0.215 sec, corresponding to about 70 interrogations.

A surprising fact shown in Table 7 is that a majority of the Mode 4 interrogations were received not on the mainbeams of the interrogators, as one might have supposed, but on their sidelobes. The reason is, of course, that these are called at random times, not when the interrogators are pointing at the AMF, and that they are not SLS protected in the usual way. The Mode 4 from Ft. Fisher (at 1B) is received on the sidelobe at 50 nmi and this is probably nowhere near maximum distance for sidelobe reception.

The Mode 4 was received from No. Charleston (at 2D) on the mainbeam at a distance of 250 nmi. This is probably also nowhere near maximum distance for receiving the mainbeams.

### 3.8   Effect of Mode 4 on a Typical Transponder (Figs. 9a-9d)

In order to evaluate the detailed effect of Mode 4 interrogations on an average airborne transponder (with a 35-µs suppression time and 60-µs* dead time), a pulse-by-pulse plot was made of over 50 Mode 4 interrogations, received from Ft. Fisher, Jacksonville NAS and Patrick ARSR (at locations 1B, 1K, 1S, and 1X) (see Figures 9a through 9d).

As these plots show, there are two parts to each Mode 4. The major portion is the second portion, starting at zero time, and having sometimes as many as 30 pulses in it. This part always starts with either 4 or 5 pulses 2-µs apart, and these always precede the P3-pulse on the actual PRI of the interrogator by 161 µs. The rest of this pulse group consists of pulses 2,3, or 4 µs apart.

The major group is preceded by 4 pulses separated by 2, 3, and 4 µs, occurring 35, 27, or 19 µs before the main group, in a cyclic manner (or by no pulses at all). The up-coming mode on the PRI is indicated by one of the symbols "2", "A", "C", "A" on the right of each plot (at the end of each line of pulses).

The pulse rate that may be produced by a single interrogator using Mode 4 is very high. For example, if 34 pulses per interrogation occur at an average PRF of 330, this rate exceeds 11,000 PPS.

Note that the SLS control pulse (the P2 pulse mentioned in the last three figures for Jacksonville NAS and Patrick ARSR) is actually transmitted in the fifth position for interrogators using SLS. It is shown larger than the other pulses, since on the sidelobes shown here it is transmitted with greater power than are the other pulses. The SLS pulse (the fifth pulse) is missing entirely in the first figure, since Ft. Fisher is not using SLS at the moment.

---

*Note that the 60 µs dead time was chosen for a mix of civilian and military transponders whose individual dead times average about 35 and 100 µs, respectively, following Mode A/C interrogations. Note that average suppression lasts 35 µs for both types of transponders.

| EFFECT ON TRANSPONDER | | MODE 4 PULSES RECEIVED (AMF, 23 MAY 1979) | MODE ON |
|---|---|---|---|
| MODE 4 | PRI | TIME (US) / (O = PRI − 161 US) / −30 −20 −10 0 10 20 30 40 50 60 70 | NEXT PRI |
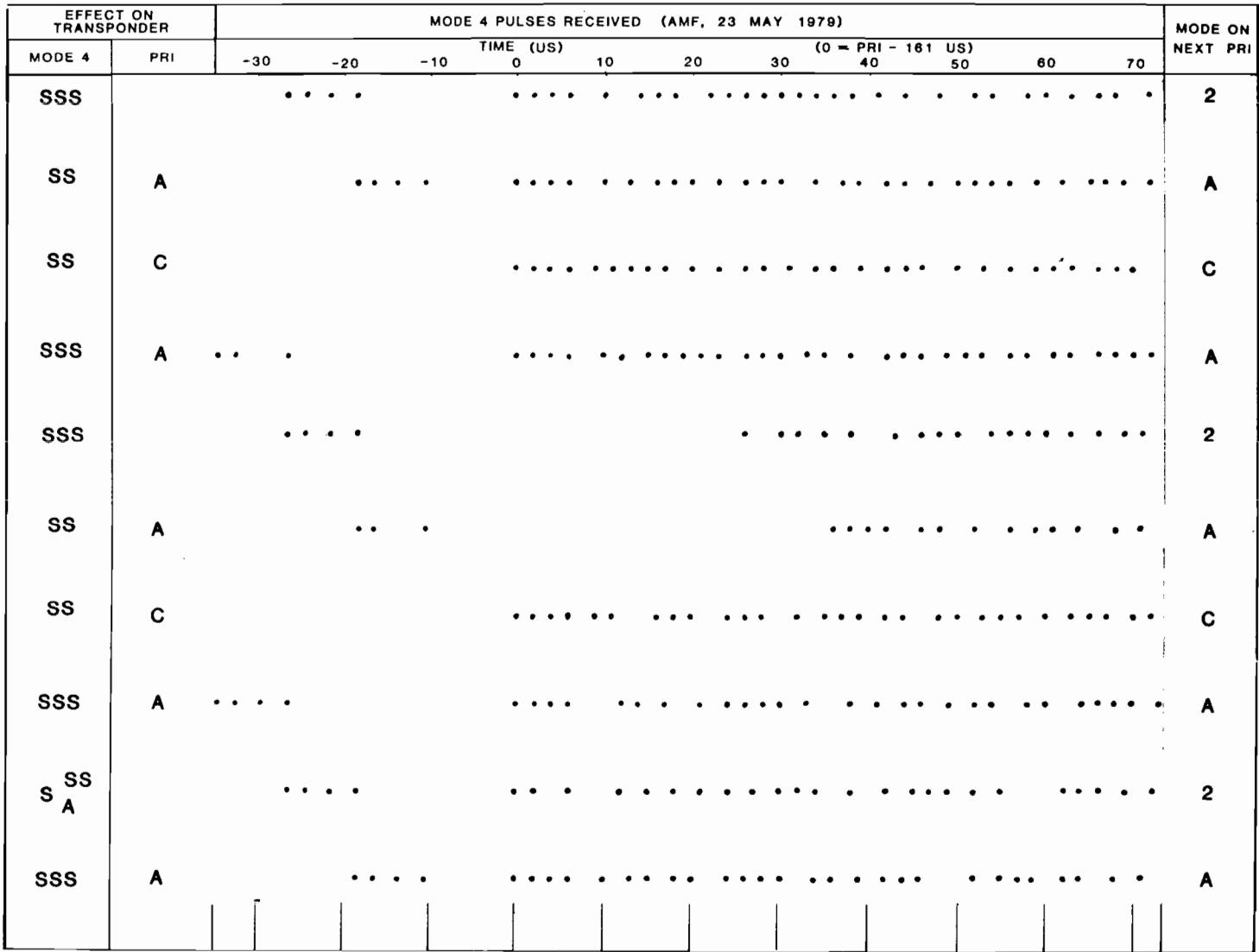


LOC. 1B 50NM WSW OF FT FISHER (INT. 15) MB + 21° NO SLS

FIGURE 9a

| EFFECT ON TRANSPONDER | | MODE 4 PULSES RECEIVED (AMF, 23 MAY 1979) | | | | | | | | | | MODE ON |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MODE 4 | PRI | TIME (US) | | | | | | (0   PRI – 161 US) | | | | NEXT PRI |
| | | −30 | −20 | −10 | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | |
| SSS | S | | | | | | | | | | | | 2 |
| SSS | S | | | | | | | | | | | | A |
| SS | S | | | | | | | | | | | | C |
| SSS | S | | | | | | | | | | | | A |
| SSS | S | | | | | | | | | | | | 2 |
| SSS | S | | | | | | | | | | | | A |
| SSS | S | | | | | | | | | | | | C |
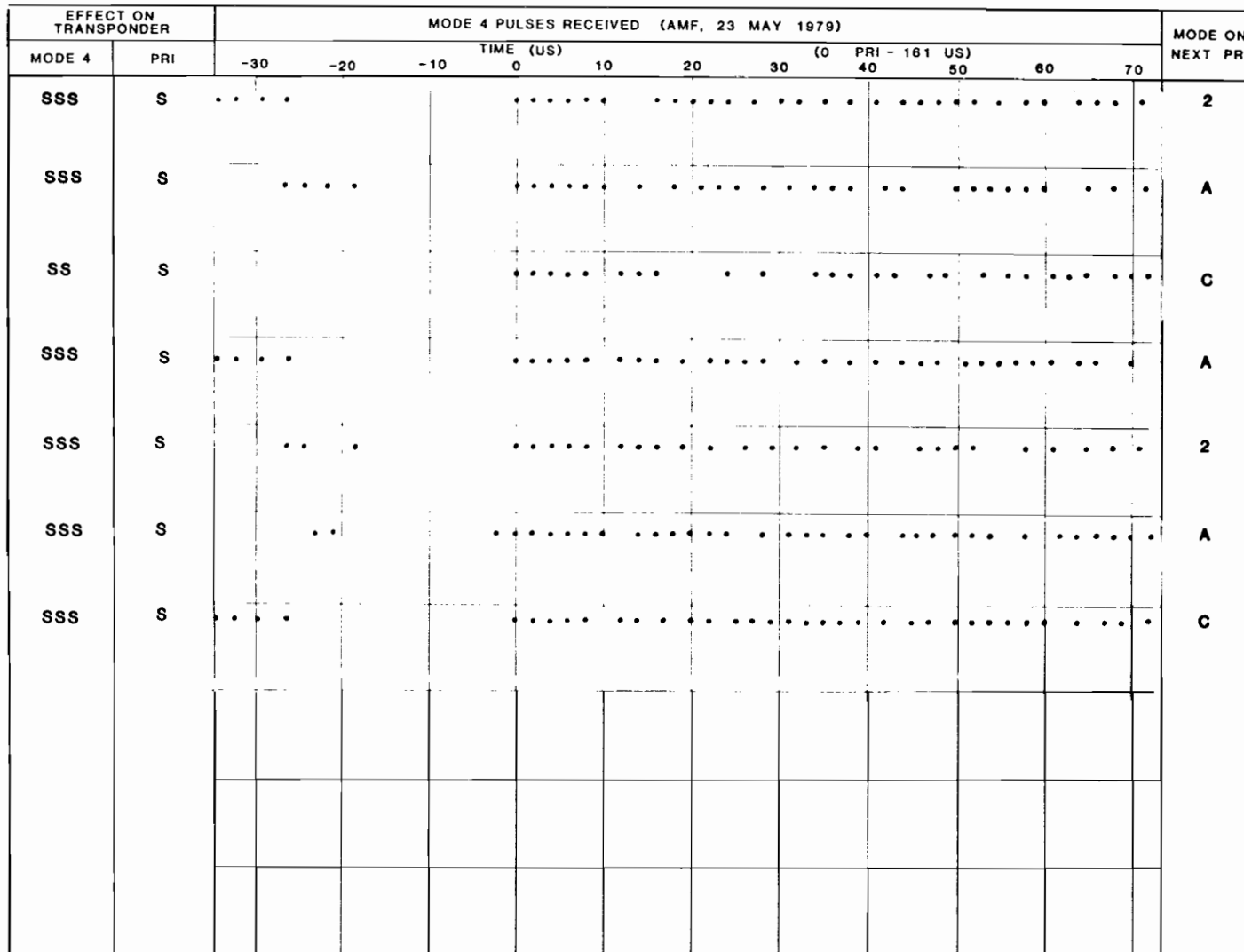
51

LOC. 1K 35NM WSW OF JACKSONVILLE NAS (INT. 24 )

REGULAR SLS MB + 68°   P2 – P1 = 10DB

FIGURE 9b

| EFFECT ON TRANSPONDER | | MODE 4 PULSES RECEIVED (AMF, 23 MAY 1979) | | | | | | | | | | | MODE ON NEXT PRI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MODE 4 | PRI | TIME (US) | | | | | | (0 PRI − 161 US) | | | | | |
| | | −30 | −20 | −10 | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | |
| SA | S | | | | | | | | | | | | 2 |
| SSS | S | | | | | | | | | | | | A |
| SSS | S | | | | | | | | | | | | C |
| SS | S | | | | | | | | | | | | A |
| SSS | S | | | | | | | | | | | | 2 |
| SSS | S | | | | | | | | | | | | A |
| SS | S | | | | | | | | | | | | C |
| SSS | S | | | | | | | | | | | | A |
| SA | S | | | | | | | | | | | | 2 |
| SA | S | | | | | | | | | | | | A |
| SSS | S | | | | | | | | | | | | C |
| SSS | S | | | | | | | | | | | | A |
| SS | S | | | | | | | | | | | | 2 |
| SSS | S | | | | | | | | | | | | A |
| SA | S | | | | | | | | | | | | C |
| SS | S | | | | | | | | | | | | A |
| SSS | S | | | | | | | | | | | DF | 2 |

**LOC. 1S APPROX. 16NM ESE OF JACKSONVILLE NAS (INT. 24)**
**SUPPR. REGION 17° BEFORE MB P2(= −58dBm) 5 TO 10dB > P1**
**FIGURE 9c**

| EFFECT ON TRANSPONDER | | MODE 4 PULSES RECEIVED (AMF, 23 MAY 1979) | MODE ON |
|---|---|---|---|
| MODE 4 | PRI | TIME (US) ... (0 PRI - 161 US) ... -30 -20 -10 0 10 20 30 40 50 60 70 | NEXT PRI |
| AS | S | | C |
| SS | S | | A |
| SSS | S | | 2 |
| SSA | S | | A |
| SA | S | | C |
| SS | S | | A |
| SS | S | | 2 |
| S S A | S | | A |
| SS S A | S | | C |
| SSS | S | | A |
| SS | S | | 2 |
| SSS | S | | A |
| SSS | S | | C |
| SSA | S | | A |
| SS | S | | C |
| A | S | | A |
| A | S | | 2 |
| SS | S | | A |
| SA | S | | C |
| S | S | | A |

LOC. 1X 18NM S OF PATRICK ARSR (5-P STAG. ABANDONED FOR FIXED
PRF OF 360.2 DURING MODE 4) MB + 195°  TOP = BOT + 3 DB P2 = P1 + 6 DB

FIGURE 9d

### (1)  Suspension of 5-Pulse Stagger During Mode 4

The Patrick ARSR is one of the 8 FAA interrogators on 5-pulse stagger seen during the Jacksonville flight.  Its staggered PRI (shown in Figure 7) was confirmed repeatedly at each recording location by the "PRI Table" of the uplink analysis program.

An interesting observation was made while examining Mode 4 pulse-by-pulse data from Patrick:  all Mode 4 transmissions occurred on the fixed PRI of 2776.25 μs, the central PRI of the 5-pulse stagger (corresponding to a fixed PRF of 360.2).

The most likely reason for going to a fixed PRF during Mode 4 is the desire to avoid another level of synchronization at the ground receiver, in addition to normal Mode 4 synchronization.  Because of this, it is probably possible to generalize the Patrick example to all en-route interrogators on 5-pulse stagger.

### (2)  Effect of Mode 4 on Typical Transponder

The more than 50 sequences of pulses shown in Figures 9a through 9d were input into a hypothetical "average" transponder, by sliding it along the pulses from left to right, and ignoring those pulses which happened to fall into the 35 μs suppression time and/or 60 μs deadtime of the transponder.  The ensuing sequence of suppression or interrogation events are noted by the symbols "S", "A", or "C" on the left side of the plot (at the beginning of each line of pulses).

The last event on the left (somewhat separated from the others) stands for the suppression or interrogation occurring on the up-coming PRI of the interrogator (161 μs after zero time).

The symbols on the left side of these plots show that the average effect of Mode 4 on the average airborne transponder is a sequence of 2 or 3 suppressions.  Occasionally a Mode A occurs, when the coded information in the Mode 4 happens to produce three pulses with inter-pulse spacing of 4 μs each, just when the transponder is coming out of suppression or deadtime.  A second mechanism producing Mode A (or even Mode C) is marginal reception, with a large fraction of Mode 4 pulses below transponder threshold (selective reception of the right pulses).

To find the percentage of time an average transponder may be unavailable to an en-route interrogator as a result of Mode 4 interrogations by some other interrogator, the length of half a suppression (20 μs) was added to the 100 μs average pulse lengths in Figures 9a through 9d. The resulting 120 μs divided by a PRI of 3030 μs (corresponding to an average PRF or 330) comes out to almost exactly 4 percent.  This increases to 5 percent, if we add one more suppression on the regular PRI of the Mode 4 interrogator, and to 6 percent, if this is considered to be an interrogation.

### 3.9  Instantaneous Interrogation Rates (Figs. 10a-10e)

Instantaneous interrogation rates  measured at locations 1G, 1H,  and 2N+ are shown in Figs. 10a through 10e.  The rates shown include those of military modes 1 and 2, as well as  civilian modes A and C.   The left-hand scales show interrogation  rates (per second)  measured at  time increments of  0.01 secs. The right side shows the percentage of time a typical transponder with 60 μsec deadtime would be unable to reply in the presence of these rates.   Since high instantaneous rates usually result  from the overlapping in time  of "bunches" of mainbeam  and/or  sidelobe  interrogations  such a  condition  is  commonly referred to as "bunching".

The worst case of bunching observed, that at location 2M+, 24 nm  east of Whitehouse ARSR, is not shown in Fig. 10 but is treated separately  in Section 4.

It is  unfortunate that the AMF data,  and the plots, do not  include all interrogation rate peaks.   This is caused by the need to  restrict the amount of  data  recorded by  the AMF  during  its extended  periods of  flight.   As operated in  the Jacksonville  area the AMF  was set  to record  for  only one minute  out of  each 10-minute period.   Thus only  10% of the environment was observed.   In addition, so as to not overload  the printer buffer capacity of the ground-based data reduction computer,  a further  limit was placed  on the period of any one run.   The net result is that less than 5% of the uplink was available to show instantaneous interrogation rates.

#### 3.9.1 Comments on Bunching at Locations 1G, 1H, and 2M+

(1)  Location 1G
The first figure for  location 1G includes the mainbeams  (MB's) for two ASR's,  Augusta and Columbia,  in addition  to the  MB's  of two military interrogators, and the sidelobe (SL) of another one.  Since the minumum  rate (1200  interrogations/sec) that might  start reply rate limiting  (RRL)  in  a  transponder is  reached  and  exceeded, momentary RRL will occur in the figure.

The second  figure for  location  1G includes  the MB's  of  one ASR (Charleston)  and one  ARSR  (Jedburg), in  addition to  the  SL  of Beaufort MCAS (no. 18).  Instantaneous rates here remain below RRL.

55
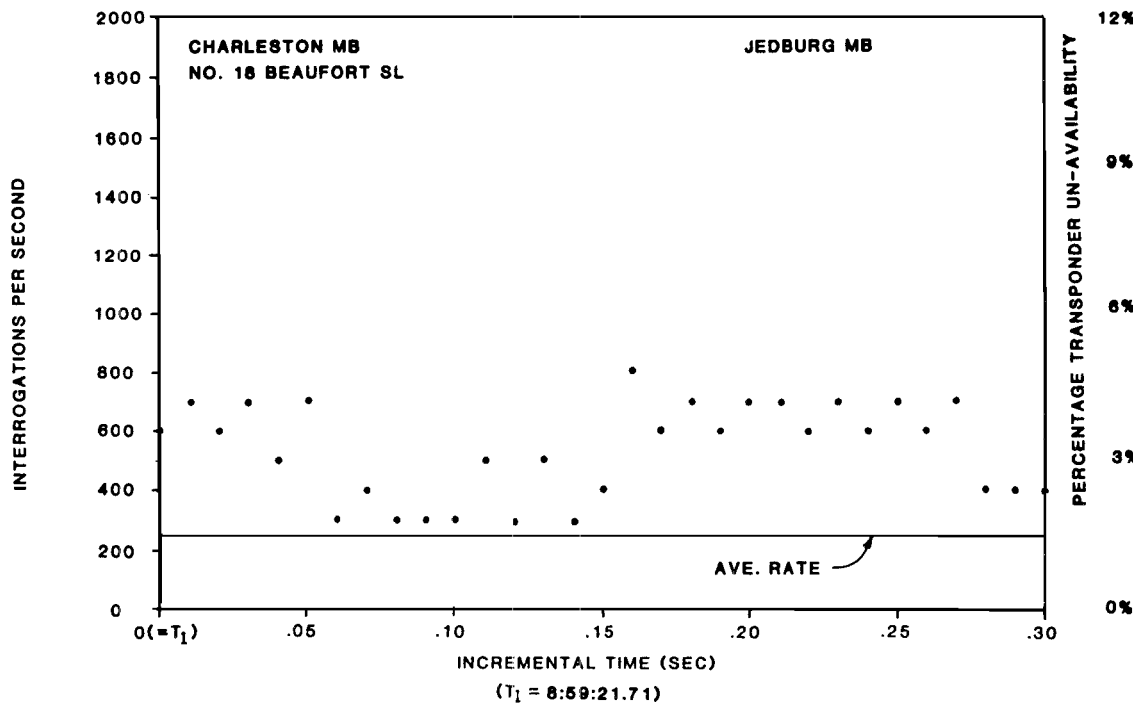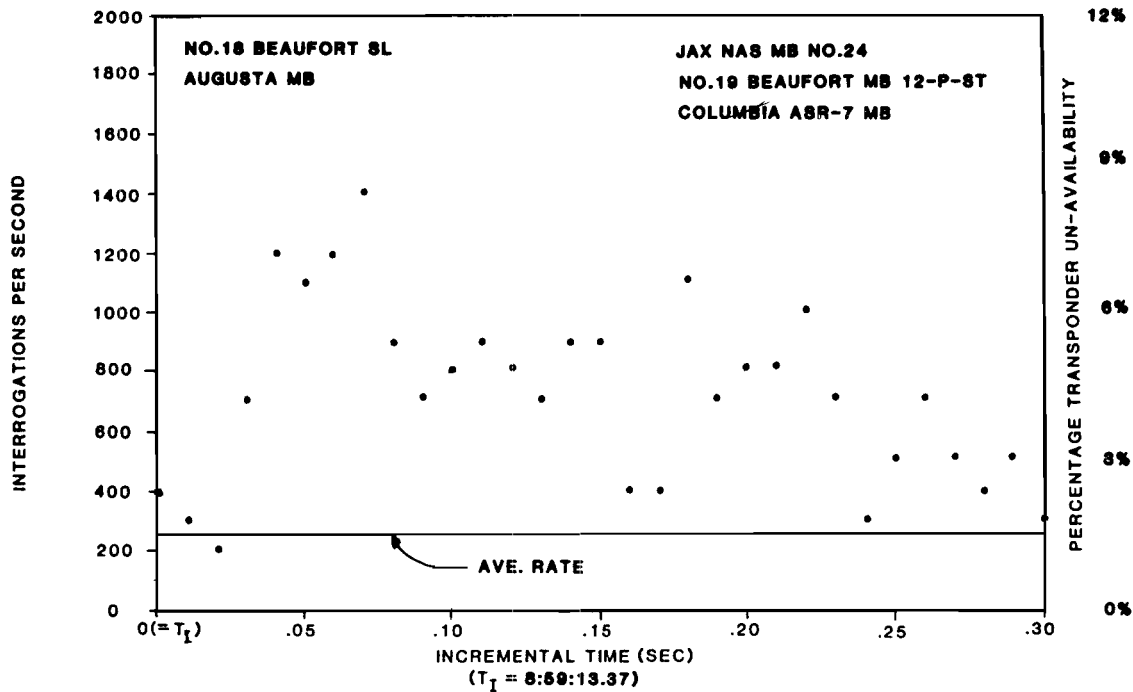
INSTANTANEOUS INTERROGATION RATE (MEASURED EVERY .01 SEC.)
LOCATION 1G 15NM SSE OF BEAUFORT MCAS

Figure 10b

NO.18 BEAUFORT MB
NO.22 9-P-ST MB
STATESBORO MB
WHITEHOUSE MB

INTERROGATIONS PER SECOND

PERCENTAGE TRANSPONDER UN-AVAILABILITY

AVE. RATE

INCREMENTAL TIME (SEC)
$(T_I = 9:9:4.87)$

NO.18 BEAUFORT MB
NO.24 JAX NAS MB
STATESBORO MB
JAX INTN'L MB

INTERROGATIONS PER SECOND

PERCENTAGE TRANSPONDER UN-AVAILABILITY

AVE. RATE

INCREMENTAL TIME (SEC)
$(T_I = 9:9:14.37)$
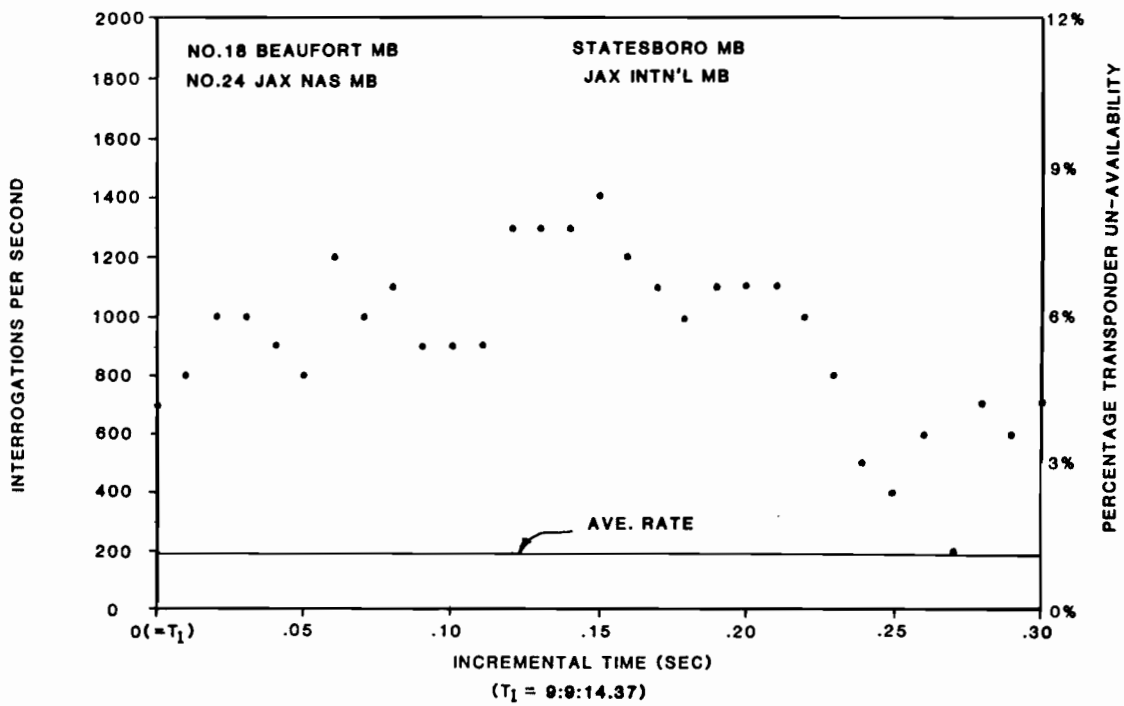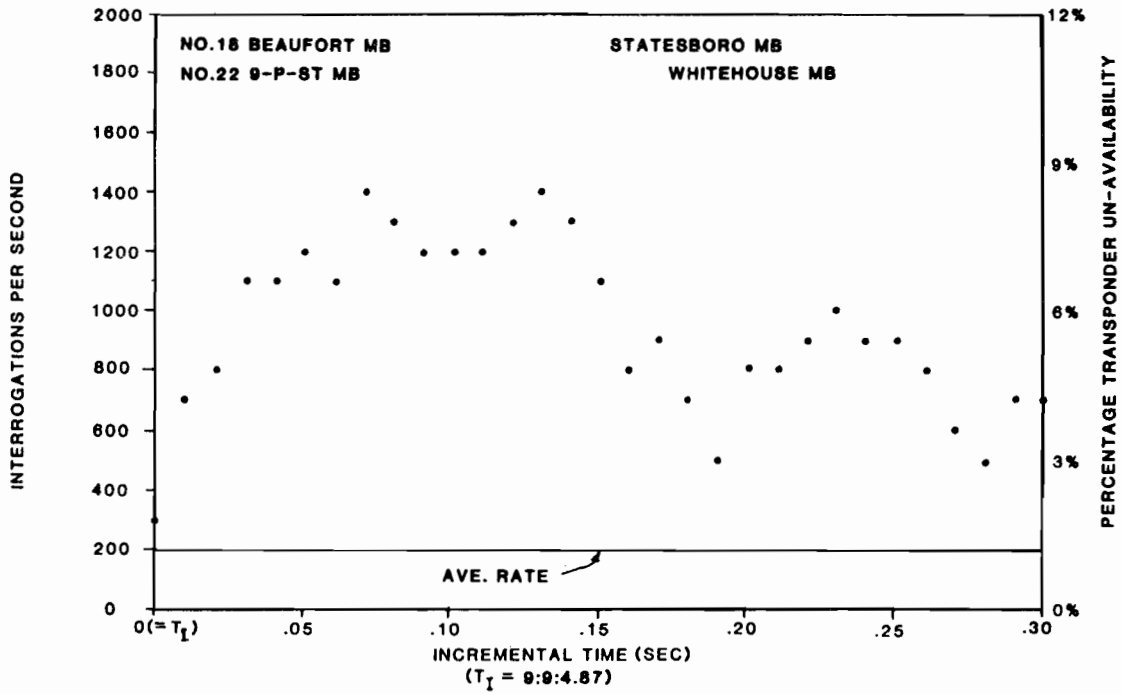
INSTANTANEOUS INTERROGATION RATE (MEASURED EVERY .01 SEC.)
LOCATION 1H 16NM SE OF SAVANNAH

Figure 10d

57
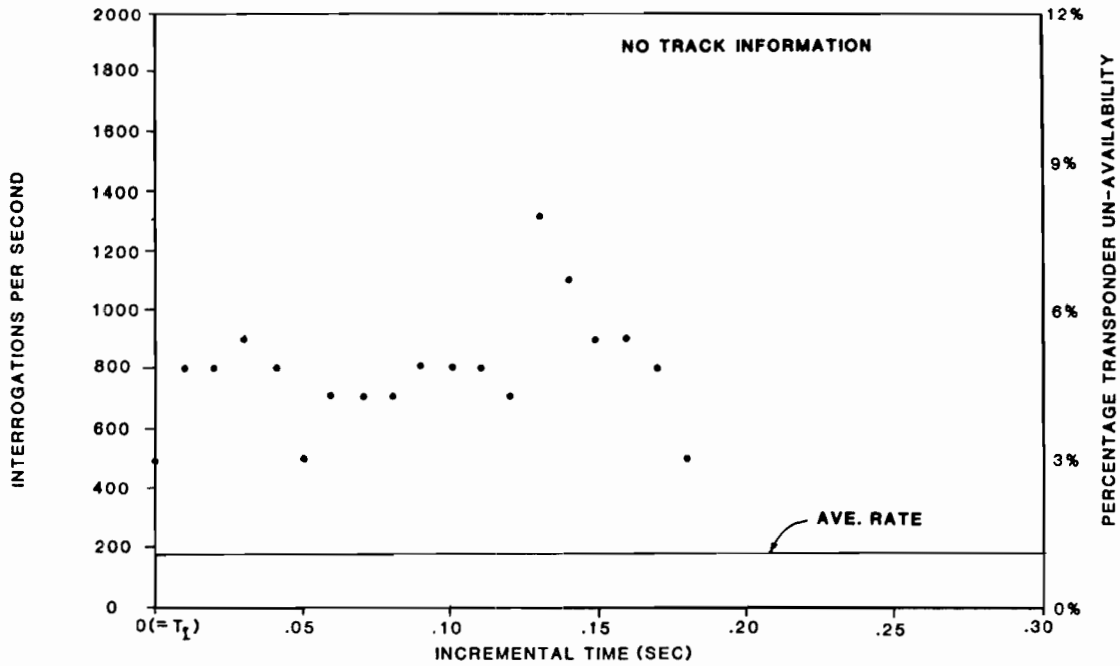
INSTANTANEOUS INTERROGATION RATE (MEASURED EVERY .01 SEC.)
LOCATION 2N + 35NM E OF WHITEHOUSE ($T_I$ = 15:34:8.70)
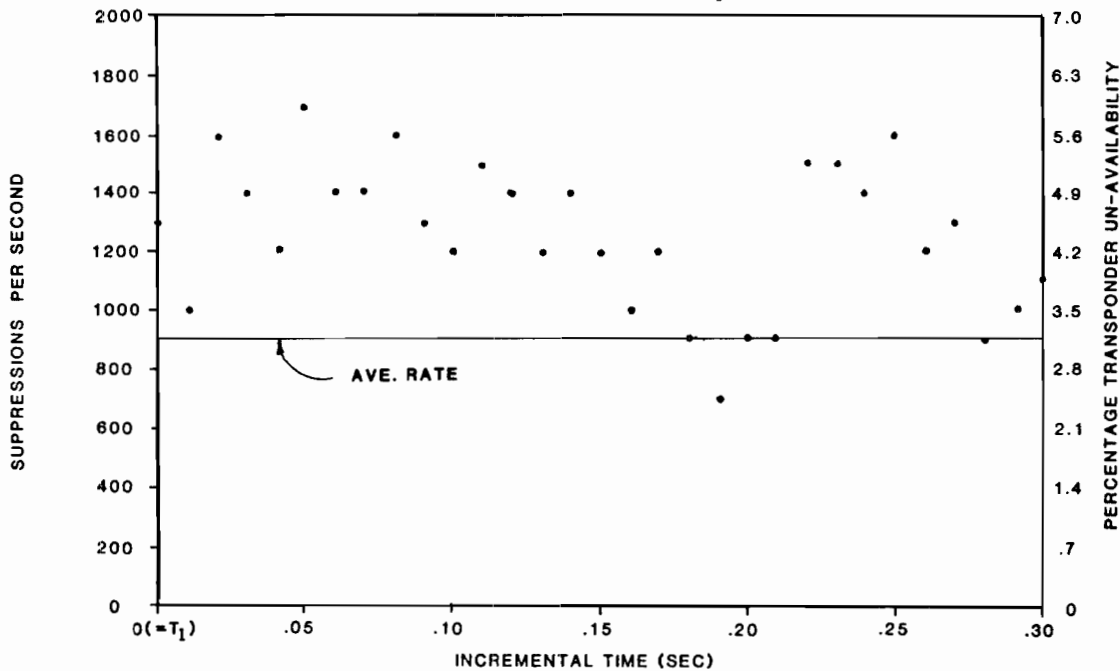


INSTANTANEOUS SUPPRESSION RATE (MEASURED EVERY .01 SEC.)
LOCATION 1L 2NM OF JACKSONVILLE INTN'L ($T_I$ = 9:49:26.70)

Figure 11a

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## Figure 11b



INSTANTANEOUS SUPPRESSION RATE (MEASURED EVERY .01 SEC.)
LOCATION 1V 30NM NW OF CAPE CANAVERAL  22NM S OF DAYTONA BEACH
($T_I = 11:29:11.72$)



INSTANTANEOUS SUPPRESSION RATE (MEASURED EVERY .01 SEC.)
LOCATION 1W ABOUT 10NM W OF CAPE CANAVERAL
($T_I = 11:39:12.35$)

## Figure 11c

59
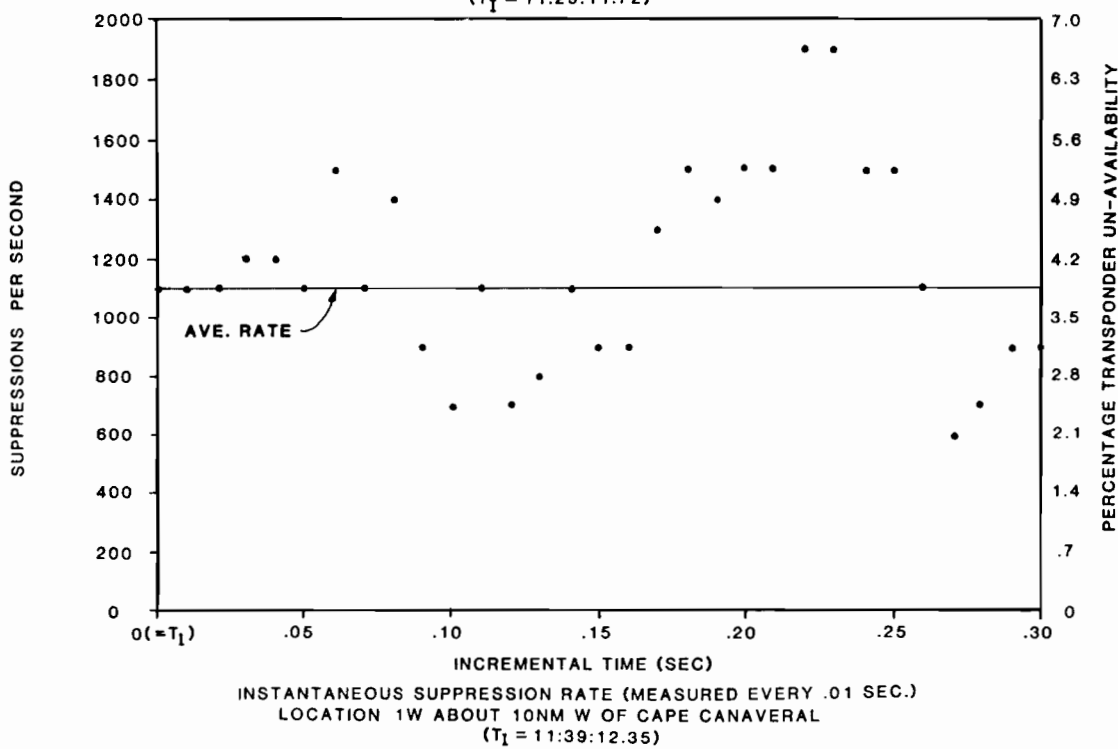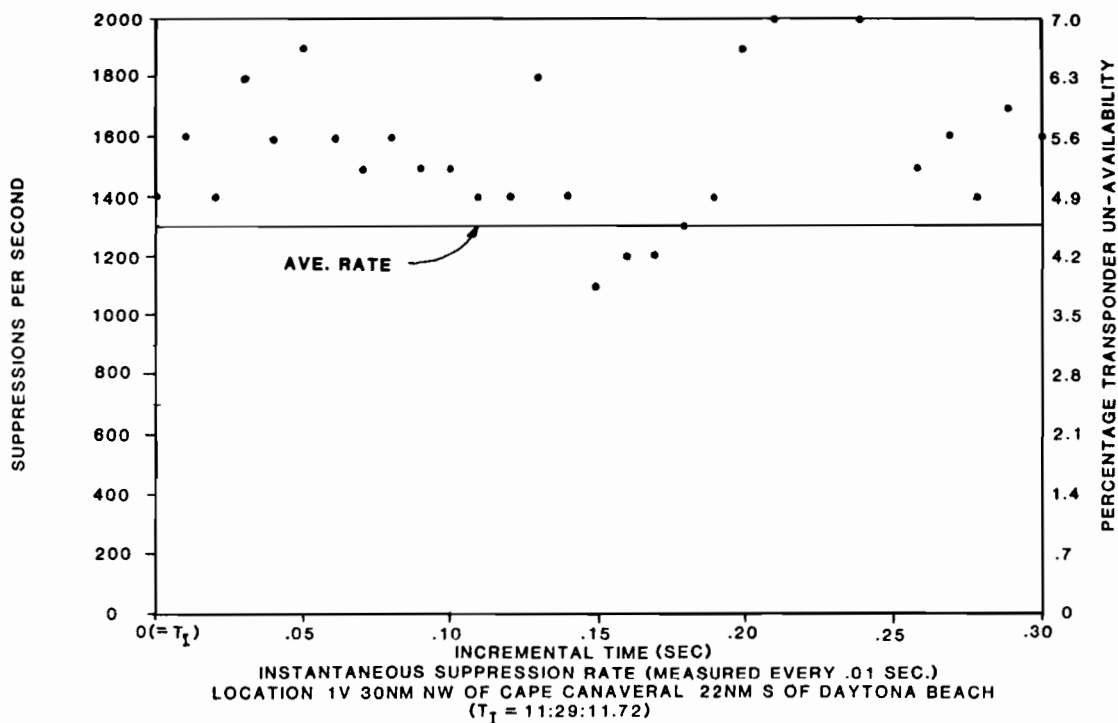
(2) Location 1H

   The first figure for location 1H includes the MB's of Whitehouse
   ARSR and three military interrogators. RRL may occur for a tenth of
   a second here, and pose a threat for almost the whole sample
   period.

   The second figure for location 1H shows the MB's of three military
   interrogators and one ASR (Jacksonville International). RRL is
   briefly exceeded, and it is a threat for about 0.2 seconds.

(3) Location 2N+

   The figure for location 2N+ threatens with reply rate limiting for
   about 0.15 seconds. Interrogators could not be identified here,
   since the uplink analysis program did not run to completion.

Transponder unavailability in these figures runs from about 2 to 8
percent for the assumed "average" transponder with 60 μs deadtime. The 8
percent level of unavailability is fairly significant by itself. It may
become quite significant due to reply rate limiting, resulting in possible
target report and track loss.

Even though these measurement locations were selected to show the
occurrence of severe bunching, bunching is more widespread than indicated. In
fact, it occurs at most locations where a dozen or more interrogators, some
without SLS, are present, regardless of the possibly low average interrogation
rate at that location. In the five figures shown here, average rates are
exceeded by factors of 5 or 6.

Reply rate limiting is usually not evident in the observed data directly,
but rather as a threat only. Frequently bunching occurs at a deceptively low
level of perhaps 800-900 IPS. A potential threat to situations like these is
the sudden turning on of a military interrogator (without SLS) in the vicinity
(which was dormant, and therefore undetected, on the day of the flight). The
sidelobe of even one of these could then increase the existing moderate
bunching into reply rate limiting and possible track loss.

## 3.10 High Instantaneous Suppression Rates Observed (Figs. 11a-11c)

Figures 11a through 11c show high instantaneous suppression rates observed at locations 1L, 1V and 1W, which may interfere with normal transponder availability, especially if it should occur together with reply rate limiting. The right hand scales are given in percentage unavailability for an average transponder with 35 μs suppression time.

(1) Location 1L

Location 1L puts the AMF 2 nmi south of Jacksonville International (337 PRF, ISLS), 11 nmi northeast of Whitehouse (365 PRF, SLS), 14 nmi north of the two interrogators at Jacksonville NAS (355 PRF, SLS and 289 PRF SLS), and 16 nmi northeast of the lower-powered interrogator at Cecil NAS (375 PRF,SLS). After subtracting the number of interrogations received from these per second (4 + 4 + 16 + 8 + 4 = 36), the rest of the PRF's add to 1721. This would be the highest average rate we could expect here. We actually get 907, only 53 percent of this. The way this comes about is that we get full suppression from Jacksonville International, no suppression from Cecil NAS, and 50 percent suppression from the other three interrogators with regular SLS (on the peaks of their directional antenna pattern transmitting the P1 pulse, which drops below AMF threshold at the nulls of the directional antenna).

The peak in Figure 11a at a rate of 1700 suppr/sec (6 percent unavailability) confirms the above analysis.

(2) Location 1V

Location 1V places the AMF 22 nmi south of Daytona Beach. The following 7 interrogators have peak received power in excess of -60 dBm here (peak power, PRF and suspected SLS type are shown): Daytona Beach (-49, 391, prob. ISLS); Patrick ASRS (-49, 360, ISLS); Orlando (-52, 381, ISLS); Jacksonville NAS (no. 24) (-52, 355, SLS); Patrick ASR (-57, 300, SLS); Whitehouse ARSR (-58, 365, SLS); MacDill ARSR (-59, 241, prob. ISLS).

Adding all seven PRF's for maximum possible instantaneous suppression rate, we get 2393, just enough to account for the peak shown in Figure 11b (2200 suppr/sec, signifying 8 percent unavailability).

Daytona Beach and Patrick ARSR (on ISLS) contribute about 90 percent of their PRF's (352 + 324 = 676) to the average suppression rate of 1302 suppr/sec here. The rest of the average suppression (1302-676 = 626) is supplied by the remaining 5 interrogations in decreasing percentages.

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(3) Location 1W

Location 1W places the AMF 14 nmi north of Patrick AFB. The
following 6 interrogators have peak received power equal to or
exceeding -60 dBm here (peak power, PRF and suspected SLS type are
shown): Patrick ARSR (-36, 360, ISLS); Patrick ARS (-42, 300, SLS);
Orlando (-50, 381, prob. ISLS); MacDill ARSR (-53, 241, prob. ISLS);
Tampa (-60, 347, prob, ISLS); Jacksonville NAS (no. 24) (-60, 355,
SLS).

Adding all six PRF's for maximum possible instantaneous suppression
rate, we get 1984, just enough to account for the peak shown in
Figure 11c (1900 suppr/sec, corresponding to almost 7 percent
unavailability).

We may assume that Patrick ARSR so near, using ISLS, contributes 99
percent of its PRF, or 356 suppressions, to the average suppression
rate of 1094 here. The rest of the average suppression (738) is
supplied by the remaining five interrogators in decreasing
percentages.

## 4.0 WORST CASE OBSERVED

### 4.1 Introduction

This section describes location 2M+, where the largest number of interrogators (31) were observed at the same time. As might be expected, this occurred at the point of nearest approach to Jacksonville on the 25,000 ft. radial toward JAX VORTAC, 24 nmi east of Whitehouse ARSR. The section includes:

- A list of the 31 interrogators present at 2M+, with their effective beamwidths (Table 8);

- Plots of the high instantaneous interrogation rates around 2 consecutive mainbeams of Jedburg, Patrick, Aiken, Whitehouse, and Valdosta ARSR's (Figures 12a to 12h);

- A graphical representation of instances of mainbeam coincidence for the 31 interrogators at 2M+, for the 10 minutes following the measurements at 2M+, extrapolated from scan periods measured at the start (Figure 13).

### 4.2 Average Beamwidth for Interrogators at 2M+ (Table 8)

Table 8 gives a list of the 31 interrogators seen by the AMF at location 2M+, with their "effective" beamwidths which include all sidelobe interrogations.

## TABLE 8

### "EFFECTIVE" BEAMWIDTHS (DEG) OF 31 INTERROGATIONS SEEN AT LOC. 2M+
#### (includes all sidelobe interrogations)

| Interrogator No. | Name | Effective Beamwidth | Interrogator No. | Name | Effective Beamwidth |
|---|---|---|---|---|---|
| 12 | Charleston ASR | 1.56 | 36 | Tallahassee ASR | 2.75 |
| 13 | Jedburg ARSR | 3.52 | 37 | Macon ASR (Robbins) | 4.31 |
| 14 | No. Charleston | 4.79 | 38 | Astor Park | 2.96 |
| 17 | Aiken AFS ARSR | 2.35 | 39 | Patrick AFB ARSR | 2.97 |
| 19 | Beaufort MCAS | 15.01 | 40 | Patrick AFB ASR | 4.13 |
| 21 | Augusta ASR | .93 | 41 | Orlando ASR | 3.05 |
| 22 | Shipborne Near 2K | 12.70 | 42 | Tampa ASR | 3.65 |
| 24 | Jacksonville NAS | 9.80 | 44 | Mac Dill AFB ARSR | 2.37 |
| 25 | Savannah ASR | 3.08 | 48 | Shipborne Near 2K | 21.03 |
| 28 | Valdosta ARSR | 3.93 | 49 | Mayport NS | 58.00 |
| 29 | Whitehouse ARSR | 4.19 | 51 | Mac Dill AFB | 8.97 |
| 30 | Jacksonv. Intern. AR | 5.09 | 52 | Mac Dill AFR | 3.00 |
| 31 | Jacksonville NAS | 6.07 | 60 | Panama City ARSR | 1.90 |
| 32 | Beaufort MCAS | 3.90 | 61 | West of Loc. 2M+ | 2.64 |
| 33 | Cecil NAS | 4.65 | 62 | South of Loc. 2M+ | 4.37 |
| 35 | Daytona Beach ASR | 4.17 | | | |

## 4.2.1 "Effective" Beamwidths Include Sidelobes

Sidelobe interrogations, when present, increase the probability of being interrogated above the value based solely on the beamwidth of an interrogator. To account for the difference to first order, the beamwidth given by the program must be multiplied by the ratio of total interrogations to mainbeam interrogations (per scan). All but 12 of the 31 entries in Table 8 show "effective" mainbeams widened in this manner.

Before the calculation of average beamwidth needed for the probability calculations below, interrogator 49 (Mayport Naval Station) with a beamwidth of 58 deg was replaced by two interrogators with beamwidths of 29 deg each. This was done because it had a PRF (657) double the usual value, and because the division gives another degree of freedom to the strong sidelobes of Mayport.

The average effective beamwidth for the interrogators in Table 8 is 6.59 deg. Dividing this by 360, we obtain $p = 0.0183$ for the probability of being interrogated by an average interrogator at some instant of time. The value $p = 0.0183$, with $q = 1-p = 0.9817$ will be used below (see Appendix A).

## 4.3 FAA ARSR Mainbeams at Location 2M+

Marginal instantaneous interrogation rates* (at the time of occurrence of the mainbeams of five FAA enroute interrogators) are described next. Often these rates are not high enough to cause actual reply rate limiting (RRL nominally starts at 1200 IPS, some transponders possibly being set lower). Marginal rates also arise during multi-PRF "synchronous jamming" between interrogators on near-equal scan periods, discussed in Appendix B. The addition of even a single close-by military intrrogator without SLS (which was silent during data recording) would force all marginal situations with incipient RRL into active RRL with all its implications (desensitization, track loss, etc).

The eight figures described here (Figures 12a through 12h) show (high) instantaneous interrogation rates near 2 consecutive mainbeams of the Jedburg, Patrick, Aiken, Whitehouse and Valdosta ARSR's and suggest reply rate limiting (RRL) and the possibility of missed target reports and/or track loss. (Transponder unavailability given below must be incremented by 3 percent due to the 850 suppr/sec at location 2M+.)

The instantaneous rates reported included all modes ("1", "2", "A", "C").

### (1) The Jedburg Mainbeams (Fig. 12a-12b)

Figures 12a and 12b show only a single point (at 1400 IPS) where reply rate limiting (RRL) would occur, but a strong threat of RRL in the sense described above (via the addition of an interrogator without SLS) exists throughout.

Something unusual happens to Jedburg at this location: its third mainbeam is missing. Peak received power drops by 5 dB from the first mainbeam to the second (-67 dBm vs -72 dBm at the bottom antenna of the AMF). There is another 9 dB loss from the second mainbeam to the three or four interrogations present on the third mainbeam (at -72 dBm). None of this is due to aircraft maneuvering and Jedburg certainly could not be counted on for surveillance here.

### (2) The Patrick and Aiken Mainbeams (Fig. 12c-12d)

Figures 12c and 12d include 2 consecutive mainbeams of Patrick and of Aiken, which follow the Patrick mainbeam by about 0.16 sec. This separation between the two mainbeams is increasing, since the interrogator having the later mainbeam (Aiken) also has a 0.005 sec longer scan period than does Patrick, making it that much later every scan.

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*Rates that approach reply rate limiting.

The Jedburg Mainbeams
Figure 12a-b
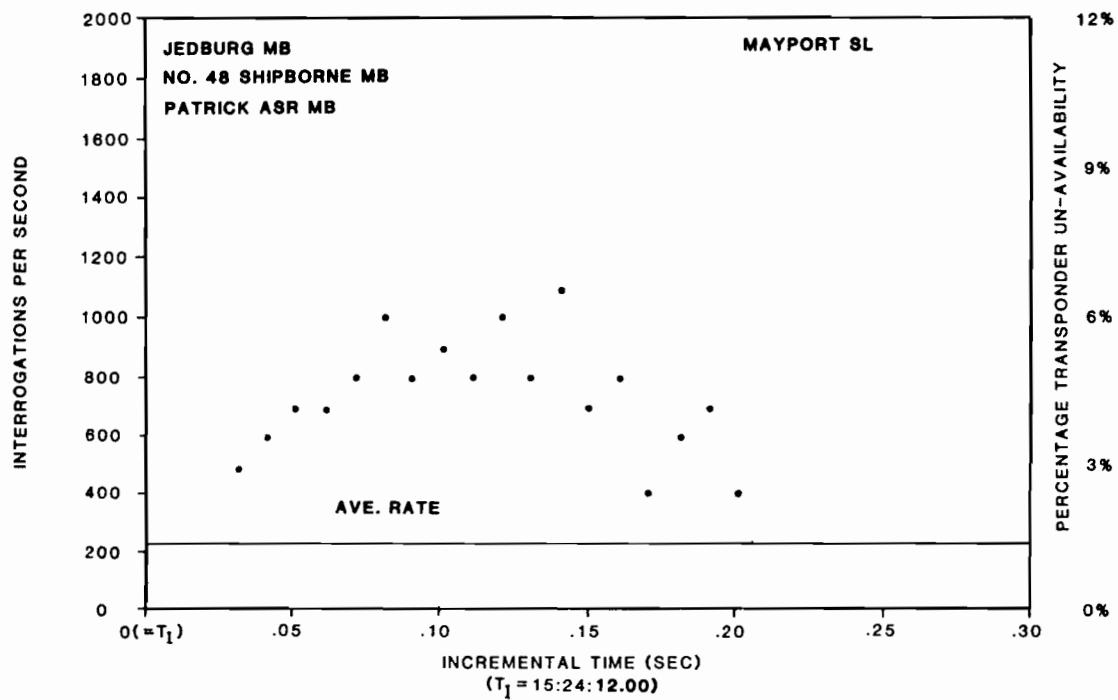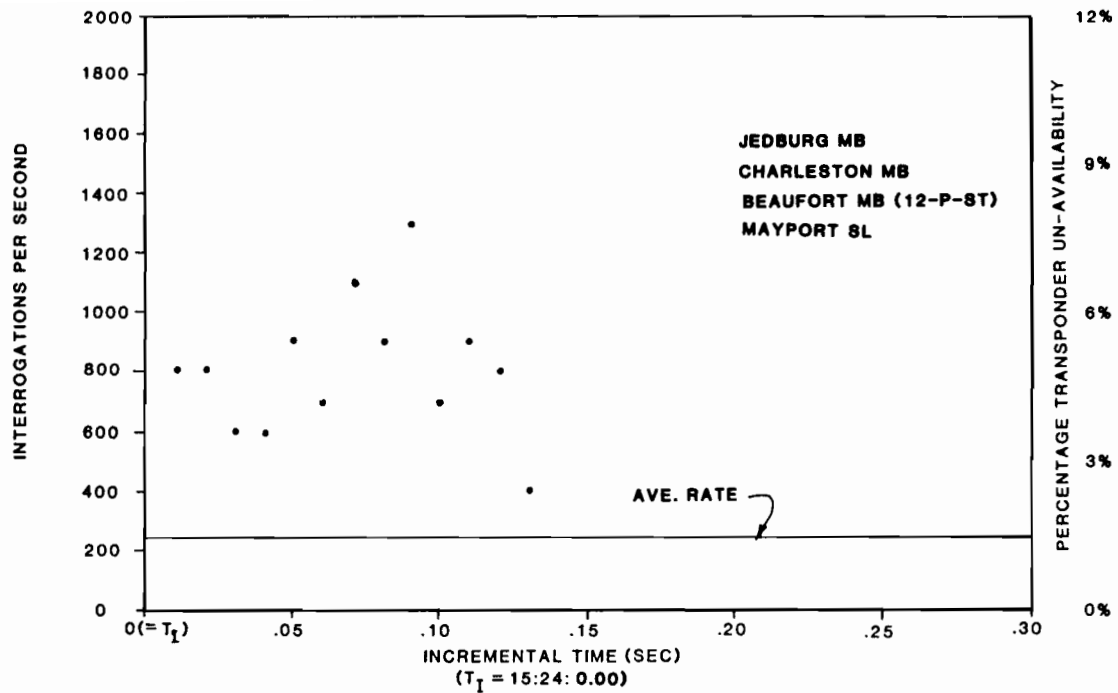
INSTANTANEOUS INTERROGATION RATE (MEASURED EVERY .01 SEC.)
LOCATION 2M+ 13 NM E OF JACKSONVILLE INTN'L

The Patrick/Aiken Mainbeams
Figure 12c-d

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The Whitehouse Mainbeams
Figure 12e-f

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The Valdosta Mainbeams
Figure 12g-h

The first figure shows a 40 ms region (peaking at 1700 IPS) where RRL would cause a desensitizing of the transponder threshold. This, in turn, would eliminate replies to Patrick, which is weak here (-72-and -75 dBm peak on the two mainbeams). The Aiken mainbeams are a little more powerful (at -67 and -68 dBm peaks). Neither Patrick nor Aiken could be counted on for surveillance here.

### (3) The Whitehouse Mainbeams (Fig. 12e-12f)

Figures 12e and 12f for Whitehouse show a double mainbeam coincidence for the first mainbeam (600 -800 IPS), but also a strong threat of RRL for the second mainbeam. Whitehouse is probably assigned primary surveillance responsibility at location 2M+. In the instances shown, this role would not be seriously threatened, since its powerful mainbeams (both at -43 dBm peak) would overcome a slight desensitization of the airborne transponders.

### (4) The Valdosta Mainbeams (Fig. 12g-12h)

Figures 12g and 12h show the 1200 IPS level exceeded, or approached, for both mainbeams of Valdosta, making some RRL and transponder desensitization a strong possibility. Valdsota power tops out at about 15 dB below Whitehouse power here (-58 and -57 dBm peak, at the bottom antenna of the AMF). In Valdosta's likely task of secondary surveillance responsibility at location 2M+ modest cases of desensitization might be handled but not strong cases.

### 4.4 Mainbeam Coincidences for 31 Interrogators at 2M+ (Fig. 13)

Figure 13 shows more than 3000 mainbeams for the 31 interrogators for 10 minutes following the measurements at 2M+, extrapolated from scan periods measured at the start. Mainbeams are superimposed (plotted vertically) for better visibility for (near) coincidences. Jedburg (-), Patrick (o) and Whitehouse (·) mainbeams are marked as shown. Each horizontal division is 1 sec. One line represents 100 sec of "fine" time. A "coarse" time of 100 sec must be added to each successive line. The number of mainbeams plotted for 600 sec total time represented by the figure is inversely proportional to the scan periods. For the most popular scan periods of 3.93, 4.70 and 12.00 sec, these are: 153, 128, and 40 successive mainbeams.

The presence of a mainbeam is shown by a mark one vertical division in height. The only exception is Mayport with its double PRF, which is plotted twice as high. An attempt was made to let the width of each mainbeam indicate the number of interrogations on it. This was not always successful, especially for the narrower mainbeams. The widened "effective" mainbeams shown in Table 8 were also used here.
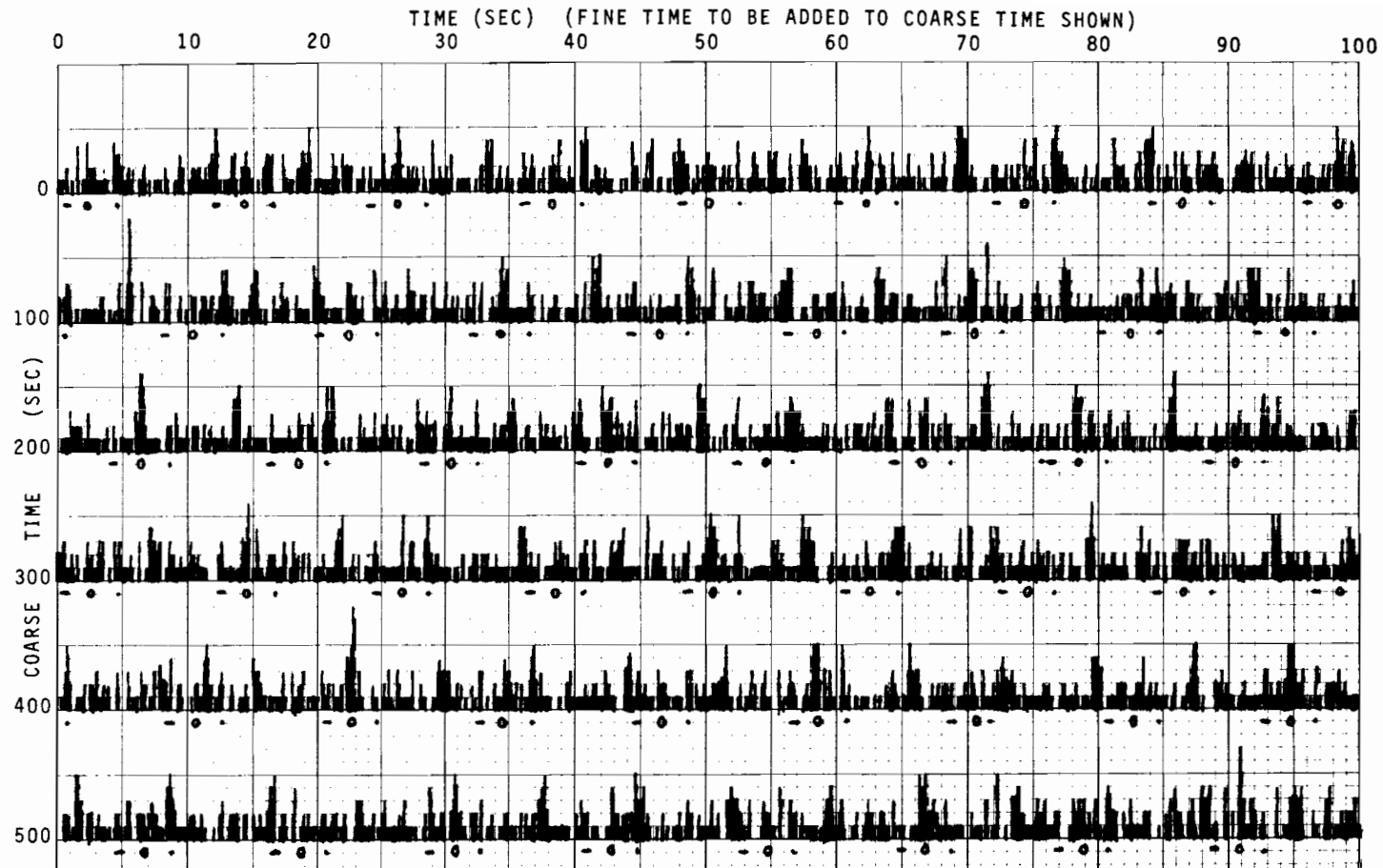
MAINBEAM COINCIDENCES FOR THE 31 INTERROGATORS OBSERVED BY THE AMF AT LOCATION 2M+
24 NM EAST OF WHITEHOUSE ARSR (AT 25,000 FT) DURING THE 10-MINUTE INTERVAL 15:24 TO
15:34, EXTRAPOLATED FROM SCAN PERIODS MEASURED AT THE START  (23 MAY 1979)
JEDBURG (-), WHITEHOUSE (·) AND PATRICK AFB (o) ARSR MAINBEAMS ARE MARKED

FIGURE 13

The fixed scan periods of Figure 13 were used to extrapolate the 31 mainbeams for the 600 sec shown in the figure. Actual scan periods, however, are not absolutely fixed. They change with time, according to the changes in the tangential component of aircraft velocity. Changes are most noticeable in the scan periods of the nearest interrogators.

The unchanging scan periods in Figure 13 actually are scan periods that would be observed by aircraft hovering at 2M+ or entering 2M+ for the 10 minutes following the measurements.

## 4.5 Discussion of the 3000 Mainbeams

### 4.5.1 General Remarks

Figure 13 shows that about half of the baseline has at least one mainbeam occupying it. This is in fairly good agreement with the probability of being interrogated by at least one interrogator (P(I) = 0.446) calculated in Appendix A.

Double, triple, and higher order mainbeam coincidences are more and more exaggerated in the plot with respect to their calculated values. But, since the calculations are based on a 5 to 10 percent sample of the uplink on a day when only one third of the military interrogators listed in the ECAC file for the area were observed, it was felt that the unmeasured 90 to 95 percent would have produced "worst case" multiple mainbeam coincidences every bit as bad as the figure even on the day of the flight, not to mention flights on days of really heavy military activity.

As may be imagined, a single military interrogator without SLS, near enough for 100 percent sidelobes reception, would raise the whole plot vertically by the height of one mainbeam (1 division), and two such interrogators, or one on a "double PRF" like Mayport NS, would raise the plot by 2 divisions. Therefore a more accurate extrapolation of the "worst case" into an actual worst case might produce a strong increase in single and double interrogations there. Note that double or higher interrogations would probably produce triple or quadruple interrogations of the same frequency in the hypothesized worst case.

## 4.6 Predicted Mainbeam Coincidences for ARSR's

Examination of Figure 13 reveals that the relative positions of the mainbeams of the three interrogators marked in the figure remain almost unchanged during the 10 minute period covered by the figure. This happens because of their near-equal scan periods. Numbering these 1 (Jedburg), 2 (Patrick) and 3 (Whitehouse), the following will be calculated (for both the first and the second pair):

- Time to complete mainbeam coincidence;

- Number of partially "jammed" mainbeams before clearance;

- Repetition time of mainbeam coincidences.

For the calculations the following items are needed: the time of occurrence (T1, T2, T3) of the mainbeams, the scan periods (S1, S2, S3) of the interrogators, and the dwell times (W1, W2, W3) of the interrogators (actually we need only the time differences T2-T1 = DT21, T3-T2 = DT32, and the differences in scan period S1-S2 = DS12 and S2-S3 = DS23).

Jedburg     T1 = 0.059 sec     S1 = 12.018803 sec     W1 = 0.117 sec

Patrick     T2 = 2.252 sec     S2 = 12.011305 sec     W2 = 0.099 sec

Whitehouse  T3 = 4.358 sec     S3 = 12.006673 sec     W3 = 0.133 sec

$\qquad$ DT21 = 2.193 sec     DS12 = 0.007498 sec

$\qquad$ DT32 = 2.106 sec     DS23 = 0.004632 sec

### 4.6.1 Time-to-Go for Mainbeam Coincidences

Since S1 is greater than S2, each scan brings MB1 closer to MB2 by DS12 sec, the difference between the scan periods. Therefore the number of scans needed to close the time gap of DT21 sec between MB2 and MB1 is just DT21/DS12, the time difference divided by the scan difference. Multiplying this by the scan period S1 gives the time to go in seconds. Thus, for the time to go to the Jedburg/Patrick overlap:

$$\frac{DT21}{DS12} = \frac{2.193}{.007498} = 292.48 \text{ scans or } 3515.23 \text{ sec or } 0.976 \text{ hours}$$

Similarly, for the time-to-go to the Whitehouse/Patrick overlap:

$$\frac{DT32}{DS23} = \frac{2.106}{.004632} = 454.66 \text{ scans or } 5461.10 \text{ sec or } 1.517 \text{ hours.}$$

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### 4.6.2 Number of Partially "Jammed" Mainbeams (Duration)

If the duration of each overlap is defined as lasting from the time the mainbeams first touch to the time they completely separate again, the duration is given by the sum of the dwell times for the two interrogators (W1 + W2 = L12 and W2 + W3 = L23 in our case). We again have to divide these by the differences in the scan periods to express them in terms of the number of scans they last. Thus, for the duration of the Jedburg/Patrick overlap:

$$\frac{L12}{DS12} = \frac{0.216}{0.007498} = 28.8 \text{ scans or } 346.23 \text{ sec or } 5.77 \text{ minutes}$$

Similarly, for the duration of the Whitehouse/Patrick overlap:

$$\frac{L23}{DS23} = \frac{0.232}{0.004632} = 50.1 \text{ scans or } 601.6 \text{ sec or } 10.03 \text{ minutes.}$$

The number of partially jammed mainbeams is 29 for the Jedburg/Patrick overlap, and 50 for the Whitehouse/Patrick overlap. This result has disturbing implications, especially for a pair of enroute interrogators having primary and secondary surveillance responsibilities for a given area. The extended length of "synchronous jamming" makes the interrogators involved vulnerable to "pop-up" military interrogators as well as other synchronous jammers (interrogators of near-equal scan period).

### 4.6.3 Repetition Time of Mainbeam Coincidences

Finally, we want to calculate the repetition time of mainbeam coincidences for the above interrogators. In this connection we know that, for a pair of interrogators, the overlaps repeat whenever we go through n scans, such that n times the longer scan period equals (n+1) times the shorter scan period. In our two cases we have nxS1 = (n+1)xS2 and mxS2 = (m+1)xS3, since S1>S2>S3. The first equation is equivalent to nx (S1 -S2) = S2 and to n = S2/(S1-S2) = S2/DS12. Thus we get for the repetition time of the Jedburg/Patrick mainbeam coincidences:

$$n = \frac{12.011305}{0.007498} = 1602 \text{ scans or } 19253 \text{ sec or } 5.34815 \text{ hours}$$

Similarly, for the repetition time of the Patrick/Whitehouse mainbeam coincidences:

$$m = \frac{12.006673}{.004632} = 2592 \text{ scans or } 31135 \text{ sec or } 8.64852 \text{ hours}$$

### 4.6.4 Percent "Jammed" Mainbeams

Having now obtained both the lengths of the partial overlaps (346 and 602 sec) and their periods of repetition (19253 and 31135 sec), the first set can be divided by the second set to arrive at some percentages. The results are 1.8 and 1.9 for the overall percentage of mainbeams partially jammed by the Jedburg/Patrick and Patrick/Whitehouse overlaps, respectively.

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## 5.0 AMF COVERAGE DATA COMPARED WITH FAA ENROUTE RECORDINGS

### 5.1 Target Reports From the FAA Enroute Interrogators

FAA enroute interrogators generate "target reports" which include range, azimuth, transponder code, mode C altitude and a time of validity for each aircraft within their area of coverage. These are generated when the narrow pencil beam of the antenna points directly at the aircraft. Target reports for any given aircraft are, therefore, separated from each other by the scan period of the interrogator (usually 12 seconds).

### 5.2 Tape Recordings of Multi-Site Target Reports

The FAA is equipped to make magnetic tape recordings of target data for a number of interrogators at the same time for any length of time. Each tape includes target reports for all aircraft "seen" by the interrogator. It is possible to extract only those having a specified transponder code. If that code has been assigned to a single aircraft only, a printout may be generated of the target reports of that aircraft alone. In this manner, printouts were generated using the unique code of the Cessna 421 flying the AMF.

### 5.3 Coverage Measured Two Ways (Ground-Based and Airborne)

If a ground recording is started before an interrogator first acquires an aircraft, and it is continued beyond the time it loses the aircraft again, a record is made of the total "coverage" (visibility) along the air route flown by the aircraft. If the aircraft involved is capable of recording the interrogations arriving from the ground, and, through computer analysis, converting these into a coverage measurement of its own (as is the AMF aircraft), the two (airborne and ground-based) coverage measurements may be directly compared.

Two important questions that may be asked are:

(1) Do the coverages (visibilities) measured in two different ways yield the same results?

(2) Can missing target reports on the ground be explained through the data recorded by the AMF?

## 5.4 The Extent of the Two Coverages Compared

Ground interrogators provide surveillance information by decoding replies sent to them by the airborne transponders installed on all aircraft. In the case of the Cessna 421 flying the AMF, the transponder was a King KXP-775 with a sensitivity of -70 dBm at the antenna (mounted at the bottom of the aircraft, about 12 ft. from the bottom antenna of the AMF).

The AMF records all pulses at 1030 MHz (the ground interrogator channel), with their time of arrival, angle of arrival, width, and power received on the top and bottom antennas. After the flight, the AMF uplink analysis program first converts these pulses into a set of interrogations, then (using the underlying PRF's) detects the presence of all the individual interrogators at the point where the measurements were made. For the interrogators detected this way, we say that their AMF-measured coverage extends to the point in question. (Bottom antenna power was selected by the program over a threshold of -75 dBm.)

During the southerly (inland) leg of the AMF flight at 10,000 ft., complete coverage recordings were made for the following enroute interrogators of the Jacksonville Center:

> Jedburg, SC.,
> Aiken, SC.,
> Whitehouse, FL., and
> Valdosta, GA.

Note that these are arranged in the order they were first observed by the AMF, as can been seen from Figure 6. Individual coverage comparisions follow. Nominal zero-degree visibility at 10,000 ft is about 125 nmi.

### (1) Jedburg Coverage Compared

The visibility matrix of Figure 6 shows that the AMF observes Jedburg from location 1A to 1J. The FAA printout starts when the AMF is at 93 nmi (between 1A and 1B), and it ends when the AMF is at 140 nmi (5 min past 1J). Solid hits end when the AMF is at 110 nmi (3 min past 1I). The two coverages are almost identical.

### (2) Aiken Coverage Compared

The AMF observes Aiken from 1C to 1J and again at 1P (a location very near 1J). The FAA printout starts when the AMF is at 148 nmi (3 min before 1B), and it ends when the AMF is at 126 nmi (1 min before 1I). Solid hits start when the AMF is at 119 nmi (2 min past 1C). The FAA printout also shows 1 min of coverage 4 min before 1P, when the AMF is at 141 nmi. The two coverages are almost identical.

### (3) Whitehouse Coverage Compared

The AMF observes Whitehouse from 1G to 1W. The FAA printout starts when the AMF is at 171 nmi (5 min past 1E), and it ends when the AMF is at 113 nmi (4 min pas 1V). Solid hits start when the AMF is at 145 nmi (5 min past 1F). The coverages are almost identical.

### (4) Valdosta Coverage Compared

The AMF observes Valdosta from 1H to 1T. The FAA printout starts when the AMF is at 141 nmi (4 min before 1H), and ends when the AMF is at 119 nmi (5 min past 1S). Solid hits start when the AMF is at 115 nmi (2 min before 1I). Once again, the coverages are almost identical.

### (5) Partial Coverages at 25,000 ft. Compared

FAA recordings were started for Jedburg and Whitehouse during the northerly leg of the AMF over the ocean at 25,000 ft, 2 min before the AMF reached location 20 (2"0"), as the AMF was heading east, 46 nmi from Whitehouse. The recordings were continued until both sites lost the AMF. Here only coverages from this point on can be compared. Note that nominal visibility at 25,000 ft is about 190 nmi.

Figure 6 shows that both sites are observed by the AMF at location 2"0", and that Jedburg visibility continues to location 2Y, where the last segment of AMF data was recorded, but Whitehouse visibility stops much earlier, at location 2S.

The FAA printout for Jedburg ends when the AMF is at 124 nmi (2 min before 2Y). During the last 7 minutes of the printout the AMF descended to 12,000 ft. in preparation to landing and re-fueling at Fayetteville, NC. Maximum (167 nmi) range from Jedburg is shown by the printout to occur at location 2R. The two coverages are seen to be identical from location 2"0" on.

The FAA printout for Whitehouse ends when the AMF is at 194 nmi (2 min past 2T). Solid hits end when the AMF is at 181 nmi (6 min past 2S). The FAA and the AMF coverages are again identical for the duration of the FAA printout.

Thus the FAA enroute recordings provide an almost 100 percent confirmation of the visibilities observed by the AMF and reported in the present paper.

### 5.5 Missing Target Reports Are Due to Marginal Propagation

Each target report for the AMF aircraft (the Cessna 421) at a given en-route interrogator corresponds to a mainbeam of that interrogator observed by the AMF at the same time. An extra target report occurs when the transponder of the Cessna replies to interrogations below the threshold of the AMF.

A missing target report occurs when the interrogations on a mainbeam are below the threshold of the Cessna transponder, or replies sent back by the transponder on 1090 MHz are below the threshold of the en-route interrogator. At times like these, the AMF may observe part or all of the corresponding mainbeam of the interrogator.

Since the AMF and the Cessna transponder are independent devices, there is not a one-to-one correspondence between the number of interrogations on any mainbeam as observed by the AMF, and the number of replies sent back by the Cessna transponder - although there is rough overall agreement.

Target reports are separated from each other by the 12-sec scan periods of the en-route interrogators involved. FAA printouts show missing (single or multiple) target reports by virtue of the fact that a "delta time" has a value of some multiple of 12 sec, rather than 12 sec (as is the case for solid reports).

During the course of this investigation, the FAA printouts for Jedburg, Aiken, Whitehouse and Valdosta were examined for missing target reports. Even though the large majority of these occurred in-between AMF recordings, enough of them were found in the common intervals of time to arrive at the following conclusions.

Missing target reports usually mean no AMF visibility, either because of low received power below the AMF theshold, or due to submarginal propagation. For those locations where AMF visibility exists without FAA visibility, the AMF consistently:

● Receives marginal power in the -70 to -75 dBm range;

● Finds fewer interrogations than on neighboring mainbeams;

● Has (almost) complete mainbeams missing.

In other words, missing target reports are consistently due to marginal uplink propagation.

# 6.0 DETAILED SUMMARY OF RESULTS

Section 6 gives a detailed summary of results presented in the body of the report. Results are summarized in order of their initial presentation.

## 6.1 Combined Uplink Environment

### 6.1.1 Southerly Leg at 10,000 Ft

Except for the Jacksonville circle, this leg coincided with the Atlantic coast line almost exactly (see Fig. 1). Pertinent data are shown in Table 1, and are plotted in Figures 2 and 3. Since over half of the high pulse rate recorded near Craig Municipal Airport (at 1R+) came from some transient rather than a bona-fide interrogator, the first leg of the flight produced fairly uniform pulse rate between 2 and 4 thousand PPS, one- to two- thirds of which were unassociated ("stray") pulses--mostly P2's of unimproved SLS used in the area. Suppressions varied more, peaking near Charleston (1E), Jacksonville (1L, 1R) and Daytona Beach (1V) (720 to 1300/sec).

Interrogation modes were fairly uniform, except at the beginning of the flight (1A, 1B, 1C), where Ft. Fisher (on 2ACA, 241 PRF) has essentially contributed 100 percent of its PRF by suspending its use of SLS for a while (it was resumed again by the end of the flight). Otherwise, mode A ran between 30 and 60/sec. Mode C ran 60-70 percent of mode A. Modes 1 and 2 ran 60-70 percent of mode C (except for the "dip" in mode 1 near the start).

### 6.1.2 Northerly Leg at 25,000 Ft

Pertinent data are shown in Table 2, and are plotted in Figures 4 and 5. The northerly leg over the Atlantic produced lower and less uniform pulse rates than did the first leg, which attained the 2 to 5 thousand PPS range only once near the midpoint of the flight (during the Jacksonville appraoch). A smaller peak of 1350 PPS developed near the start of the flight (at 2E), and a somewhat larger one (2000 PPS) near its end (2Y). Stray pulses, once again, made up 1 to 2 thirds of the total. Suppressions varied even more than they did going south, having their highest peak of 850 PPS near Jacksonville (2M+), two smaller peaks at the two ends, but deep vallies in between, at the two locations most remote from land (at 2F and 2U).

Interrogation rates started low, increased sharply along the Jacksonville radial, to decrease again some towards the end of the flight. Only mode A had a significant peak near the end, due to a single mode A interrogator (No. 55) on 1096 PRF (using SLS), which increased the ambient mode A by 20/sec. Mode A went from 11 to 73/sec from the start to the middle of the flight, to level off around 40/sec thereafter. Modes 1, 2, C and A were in the approximate ratios 1 : 2 : 4 : 8, except at 2M+ (near Jacksonville), where Mayport NS (on a PRF of 657) contributed about 80 mode 2's/sec. The dependence of pulse, suppression and interrogation rates on the distance of the AMF from land and the ground interrogators thereon is quite evident.

## 6.2  The 59 Interrogators Detected in the Data

### 6.2.1  Interrogator Parameters

The 2-part Figure 6 lists the 59 interrogators in the order they were discovered. Seven important parameters are shown for each: (1) Number; (2) Suspected Name or Location; (3) PRI; (4) PRF; (5) Mode Interlace; (6) Scan Period; (7) Stagger Period. No two interrogators have all seven parameters the same—each set of parameters is unique. Table 3 shows the interrogators sorted by PRI, while Figure 7 gives actual measured PRI for interrogators on staggered but not random PRI.

#### 6.2.1.1  Suspected Name Or Location

##### 6.2.1.1.1  FAA Interrogators

Twenty-five of the 59 interrogators are marked as ASR's or ARSR's, i.e., are thought to be FAA terminal and enroute interrogators. Eight of the 10 ARSR's are on 12-sec scan, two , on 10-sec scan. Nine of the 15 ASR's are on 4.69-sec scan, five on 3.92-sec scan, and one on 4.04-sec scan. Only one of the ASR-7's on the well-known 8-pulse stagger remains: the interrogator at W. Columbia, SC. The others have been replaced by ASR-8's on fixed PRF's.

The Jedburg and Whitehouse ARSR's use regular SLS, while the Patrick AFB ARSR uses improved SLS (ISLS). The opposite is indicated in the ECAC file. The Charleston, Savannah and Jacksonville International ASR's use ISLS, and the Patrick AFB ASR uses regular SLS. These four are in agreement with the ECAC file.

##### 6.2.1.1.2  Non-FAA Interrogators

Shipborne Near 2K (at Sea). Interrogators 20, 22, 26, 48 and 54 on PRF's of 319, 293, 247, 327 and 242 appear to be located on some ships 90-100 nm east of Whitehouse in the Atlantic Ocean. All of these use mode interlace 11112222AAAACCCC, while no other interrogator uses this exact pattern. Two pairs on the same scan may be a single interrogator (20=48 and 26=54) since they are never "on" at the same time. On the other hand, there may be many interrogators there that did not transmit on the day of the AMF flight.

Beaufort MCAS. Interrogators 18, 19 and 32 seem to be co-located here. No. 18, without the benefit of SLS, contributed 133 int/sec at nearest approach (second highest rate seen). No. 19 has the most complicated (12-pulse) stagger seen during the flight (see Fig. 7).

Ft. Fisher. The highest individual rate seen came from this interrogator (240/sec at loc. 1A). At the end of the flight, at comparable distance and peak power, the rate was down to 5/sec. Ft. Fisher apparently has SLS ( as indicated in the ECAC file), which it did not use early in the morning, but did use later on.

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Mayport NS.    Interrogator 49, located at Mayport Naval Station, has the second highest PRF (657) seen during the flight.   This is equivalent to two ordinary interrogators.   The reason it did not contribute an excessive amount is because it became inactive for 8 pulse repetition intervals after every four interrogations.   It could become a real problem, if it went on 100 percent duty factor and used civilian modes only.

Interrogator 55 Near Myrtle Beach.   This interrogator has the distinction of using the highest PRF (1096/sec) seen during the flight.   Its PRF is the third harmonic of the popular 367.5 PRF, used, e.g., by Whitehouse ARSR.   It used SLS, so it contributed only 21 int/sec, instead of perhaps 50 times as many without SLS.

Bogue and Jacksonville (NC).    Interrogators 3 and 56 were thought to be located at Bogue Field. No. 56 had the lowest PRF (133.2) of any interrogator seen.   It is suspected to be using the more usual PRF of 2 X 133.2 = 267, and blanking out every other interrogation. These interrogators may alternately be located in Jacksonville, NC (Camp LeJeune), where scan periods and modes are in better agreement with the ECAC file.   With interrogator 7 there could be a total of three interrogators at Camp Le Jeune, as shown in the ECAC file.

### 6.2.1.2   Observed PRI/PRF/Stagger Period

Of the 59 interrogators detected, 41 were observed to use fixed PRF's, while the remaining 18 use stagger.  Four of the 18 use random stagger with an "infinite" set of PRF's.   The other 14 use finite stagger, which repeats exactly after K PRF's.   Stagger lengths (K) observed were:  K = 3, 5, 8, 9 and 12.   The corresponding measured PRI are shown in Fig. 7.   The most numerous stagger observed (8 interrogators) was the NAFEC-type 5-pulse stagger.

Highest PRF's observed (see Table 3) were 1096, 657, 445.4 and 439.5 int/ sec, lowest PRF's 133.2, 200.0, 218.0 and 241.1 int/sec.

### 6.2.1.3   Observed Mode Interlace

Thirteen distinct mode interlaces were observed (see Sec. 3.3.4).   Fully half of the interrogators seen use the two most popular mode interlaces AC (sixteen) and AAC (fifteen).   Seven interrogators use mode A, five use 11112222AAAACCCC.   Five use 2ACA/4 (with Mode 4), two use 2ACA without Mode 4.

### 6.2.1.4   Scan Periods

The shortest scan periods measured were 2.18 sec (Daytona Beach ramp tester), and 2.80 sec (Astor Park).   The longest, a group of en-route interrogators with 12-sec scan.   Most popular scan periods for terminal interrogators are 3.92 sec and 4.70 sec.   Most popular en-route scan period is 12 sec.

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## 6.2.2 The "Visibility Matrix" of Figure 6

As mentioned before, the 37 left columns of Figure 6, headed by the 24 southerly plus the 13 northerly location codes constitute a "visibility matrix" where "periods" (.) indicate that the corresponding interrogator is not visible at the corresponding location, while (hexadecimal) numbers not only show the presence (visibility) of an interrogator, but also give the interrogations/minute received at that location to the nearest power of 2. There is mirror symmetry in the matrix about the line separating locations 1X and 2A, since the northerly leg essentially re-traced the southerly leg of the flight.

The interogator seen the largest number of times (29 times) is Shipboard Interrogator 22. Jacksonville NAS (No. 24) is seen second most frequently (28 times), followed by Whitehouse (25 times), No. Charleston and Jacksonville NAS (No. 31) (24 times each) and Jacksonville International (23 times).

The interrogators with the highest received local rates are Ft. Fisher and No. 18 Beaufort MCAS. High interrogation rates are also received from No. 22, one of the shipborne interrogators 100 nm east of Whitehouse.

Interrogators 60, 61 and 62 do not appear to be visible anywhere. They are shown because they were seen at loc. 2M+, at the westernmost point of the Jacksonville radial, which is not included in the visibility matrix. Note that the 37 (24+13) locations shown in the visibility matrix are also the locations where four important local results are presented in the Master List of Table 4.

## 6.3 Master List of Local Results (Table 4)

The 14-page Table 4 is a "master list" of local individual results (Int/min, AOA, Ave Power, Pk Power) at the 37 (24+13) measurement locations shown in the visibility matrix. Each line of Table 4 is a measurement location, each column is one of the 59 interrogators, arranged by number, as in Figure 6. Each interrogator heading includes the seven parameters shown initially in Figure 6. As shown at the bottom of every page of Table 4, the four items in each box are arranged for optimum information content. To convert the power to dBm at the bottom antenna of the AMF, the reader should subtract 100 from the powers, and then add 3 dB.

The exact interrogation rates from Ft. Fisher, Int. 18 (Beaufort MCAS) and Int. 22 (Shipborne Near 2K) are shown on pages 2 and 3 of Table 4A. Note that the corresponding pages of Table 4B show nothing unusual for Ft. Fisher, which apparently went back to using SLS. Beaufort MCAS (No. 18) went off the air during our return flight.

Thus neither the existence of one important military interrogator (No. 18, Beaufort MCAS), nor the propensity of another one to "over-interrogate" would have been discovered by just one leg of the flight of the AMF.

## 6.4 Three PRI/PRF Distributions

Figure 8 shows the distributions in PRI/PRF of interrogations received in 1 minute near Savannah (at 1H), Jacksonville (at 2M+) and Daytona Beach (at 1U) (the right hand scales show per sec rates). The distribution near Jacksonville is plotted in the middle, since it has more than a dozen interrogators in common (mutually visible) with the other two.

All the received PRI for interrogators on staggered PRI which fit into the PRI range of 1800-4600 $\mu$s are plotted, with the period of the stagger shown above the bars.

Savannah Distribution (1H, Fig. 8a). Even though most of the interrogators fall into a third of the range shown (2440-3460 $\mu$s), all PRI are in the "clear" (they do not overlap). The main reason is the small number of interrogators here (18 in all).

Jacksonville Distribution (2M+, Fig. 8b). As might be expected, this distribution of 31 interogators has a number of problems. Tallahassee (on 2498.5 $\mu$s) is surrounded by Macon ASR on 5-pulse stagger (2500.8 $\mu$s). Jacksonville NAS (Int. 24 on 2819 $\mu$s) is similarly surround by Panama City ARSR (Int. 60 on 2818 $\mu$s) also on 5-pulse stagger.

The second harmonic of Mayport NS (Int. 49 on 1522 $\pm$ 4 $\mu$s) extends from 3035 to 3050 $\mu$s. This range of random PRI surround No. Charleston (Int. 14 on 3040 $\mu$s). It is also within 1 $\mu$s of one of the PRI received on 9-pulse stagger (3051 $\mu$s), and is within 3$\mu$s of Int. 48 (Shipborne Near 2K) which is coming in on 3053 $\mu$s here, about 7 $\mu$s below its highest PRI observed elsewhere.

Daytona Beach Distribution (1U, Fig. 8c). The small number of interrogators (19) observed here make this distribution similar to the one at Savannah. All interrogations are in the "clear", except for Ft. Fisher (on 4146 $\mu$s), and Mac Dill ARSR (on 4147 $\mu$s), which are within 1 $\mu$s of each other.

## 6.5  Reflections Observed (Table 6)

The reflections are received from four military interrogators (No. 9 Myrtle Beach, No. 24 Jacksonville NAS, No. 31 Jacksonville NAS and No. 14 No. Charleston) which probably use regular SLS.  This is concluded since the use of ISLS would tend to suppress the reflections, and the use of no SLS would probably yield much higher interrogation rates in the vicinity of these interrogators.

Interesting reflections occur near Jacksonville International (at 1Q), where the 4.5-μs reflections undergo almost no loss, a highly unusual situation.  Observing from page 4 of Table 4A that the peak power received from Int. 31 at 1Q is about 10 dB lower at 43 (=-54 dBm) than expected, compared to the powers received at neighboring locations, we conclude that the direct interrogations undergo destructive interference, while the reflected signals (over a slightly different path) are reinforced (arrive in-phase).

The first reflections from the en-route interrogator at Jacksonville NAS (Int. 24, 12-sec scan, 355 PRF) are seen at a distance of 100 nm from a strong reflector about 1 nm south of the antenna.  Reflections also occur with the AMF west, north-west and south-east of the interrogator at closer approach.

## 6.6  Mode 4 Interrogations Observed (Table 7)

The table lists 15 Mode 4 interrogations received from the 5 en-route interrogators marked by "2ACA/4" in the mode interlace column of Fig. 6.  They are:  Ft. Fisher, Jacksonville NAS (No. 24), Patrick ARSR, Richmond AFS ARSR and No. Charleston.  Observed durations vary from .08 sec to .46 sec.  Average duration is .215 sec, corresponding to about 70 interrogations on an average PRF.

A surprising fact displayed in Table 7 is that a majority of Mode 4 interrogations were received not on the mainbeams of the interrogators, but on their sidelobes.  The reason is that these are transmitted at random times, not when the interrogators are pointing to the AMF, and that they are not SLS-protected in the usual way.  The Mode 4 from Ft. Fisher (at 1B) is received on the sidelobe at 50 nmi, and this is probably far short of maximum distance for sidelobe reception.  The Mode 4 from No. Charleston (at 2D) was received on the mainbeam at a distance of 250 nm, probably also nowhere near maximum distance for mainbeam reception.

## 6.7  Effect of Mode 4 on Typical Transponder (Figs. 9a-9d)

In order to evaluate the detailed effect of Mode 4 on an average transponder (35-μs suppression, 60 μs dead time), as well as to show detailed Mode 4 structure, a pulse-by-pulse plot was made of over 50 Mode 4 interrogations received from Ft. Fisher, Jacksonville NAS and Patrick ARSR at locations 1B, 1K, 1S and 1X (see Figures 9a-9d).

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The pulse rate that may be produced by a single interrogator using Mode 4 is very high. If, for example, 34 pulses per interrogation occur on an average PRF of 330, this rate exceeds 11,000 PPS.

The more than 50 sequences of pulses shown in Figure 9 were input into a hypothetical "average" transponder by sliding it along the pulses from left to right, and ignoring pulses both in the suppression and in the dead time regions. The resulting sequence of suppressions ("S") or interrogations ("A" or "C") are noted on the left of each line of the plots.

We have shown (in Sec. 3.8) that the Mode 4 pulses themselves cause an average transponder to be unavailable for 4 percent of the time. A suppression at the regular PRI of an interrogator increases this to 5 percent, and an interrogation at this PRI, to 6 percent. A single Mode 4 interrogator alone would not cause any problems, but it might when added to the ambient environment.

It was noted in Sec. 3.8 that an en-route interrogator on 5-pulse stagger (Patrick ARSR) suspended the stagger while transmitting Mode 4 and reverted to its central fixed PRf of 360.2/sec (corresponding to a fixed PRI of 2776.25 $\mu$s). The most likely reason for going to a fixed PRF during Mode 4 is the desire to avoid another level of synchronization at the ground receiver, in addition to normal Mode 4 synchronization.

### 6.8 High Instantaneous Interrogation Rates (Figs. 10a-10e)

Location 1G (Near Beaufort MCAS) (Figs. 10a-10b). The first figure contains the mainbeams of Augusta and Columbia. It shows the minimum rate (1200 int/sec) which may cause reply rate limiting (RRL) reached and exceeded; momentary RRL occurs in the figure. The second figure contains the mainbeams of Charleston and Jedburg. Instantaneous rates here remain below RRL.

Location 1H (Near Savannah) (Figs. 10c-10d). The first figure includes the mainbeam of Whitehouse. RRL may occur for a tenth of a second here, and it poses a threat for almost the whole plot. The second figure shows the mainbeam of Jacksonville International. RRL is briefly exceeded, and it is a threat for 0.2 sec.

Location 2N+ (50 nm east of Whitehouse) (Fig. 10e). This figure threatens RRL for about 0.15 sec. Interrogators cannot be identified, since the uplink analysis program did not run to completion.

### 6.9 High Instantaneous Suppression Rates (Figs. 11a-11c)

These figures show high instantaneous suppression rates which could interfere with normal transponder availability.

Location 1L (near Jacksonville International) (Fig. 11a). Suppressions from Jacksonville International, Whitehouse, and two interrogators at Jacksonville NAS and from Cecil NAS reach 1700/sec here, which translates into 6 percent transponder unavailability.

Location 1V (Near Daytona Beach) (Fig. 11b). Suppressions from Daytona Beach, the two interrogators at Patrick, from Orlando, Jacksonville NAS (No. 24), Whitehouse and Mac Dill ARSR reach 2200/sec here (8 percent unavailability).

Location 1W (Near Cape Canaveral) (Fig. 11c). Suppressions from the two interrogators at Patrick, from Orlando, Mac Dill ARSR, Tampa and Jacksonville NAS (No. 24) reach 1900/sec here (7 percent unavailability).

### 6.10   FAA ARSR Mainbeams at Worst Case Observed (2M+)

Location 2M+, 24 nm east of Whitehouse ARSR, was the nearest point of the second leg of the flight to Jacksonville. It is called "worst" because it had the largest number (31) of interrogators seen anywhere during the flight. Table 8 shows the interrogators visible at this location, and it gives the "effective" beamwidth for each, which includes all sidelobe interrogations.

The average for these beamwidths turns out to be 6.59 deg, or 0.0183 of a revolution (the latter is also the probability p of being interrogated by one of the 31 "average" interrogators; q = 1 −p = 0.9817 is then the complementary probability of not being interrogated by one of the 31 average interrogators). This large average beamwidth is due in large part to Mayport NS which has an effective beamwidth of 58 degrees.

Figures 12a-12h show two consecutive mainbeams of five en-route interrogators of the Jacksonville Center of the FAA. Instantaneous interrogation rates (and percentage transponder availability) are plotted around the times of occurrances of these mainbeams, and are investigated from the point of view of reply rate limiting and the possibility of track loss.

The Jedburg Mainbeams (Fig. 12a-12b). These figures show only a single point (at 1400 IPS) where RRL would occur, but a strong threat of RRL in the sense described above exists throughout.

Something unusual happens to Jedburg here: its third mainbeam is missing. Peak received power drops by 5 dB from the first MB to the second (−67 dBm vs. −72 dBm). There is another 9 dB loss to the few interrogations on the third MB. None of this is due to aircraft maneuvering, and Jedburg certainly could not be counted on for surveillance here.

The Patrick and Aiken Mainbeams (Fig. 12c-12d). The figures show a short region (peaking at 1700 IPS) where RRL would cause transponder desensitization. This would eliminate replies to Patrick, which is weak here (−74 dBm). Neither interrogator could be counted on for surveillance here, even though Aiken is 6 dB stronger.

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The Whitehouse Mainbeams (Fig. 12e-12f).   The figures show only a double coincidence (600-800 IPS) for the first MB, but a strong threat of RRL for the second MB.   Whitehouse's probable role of primary surveillance responsibility would not be seriously threatened, since its powerful MB (at -43 dBm) would overcome a slight desensitization of the airborne transponders at 2M+.

The Valdosta Mainbeams (Fig. 12g-12h).   The figures show the 1200 IPS level exceeded, or approached, for both MB's of Valdosta, making RRL and desensitization a strong possibility.   Valdosta power tops out 15 dB below Whitehouse power here (at -58 dBm).   Valdosta might be able to handle modest cases of desensitization but not strong ones, in its likely task of secondary surveillance responsibility at location 2M+.

### 6.11  Plot of Mainbeam Coincidences at 2M+ (Fig. 13)

Figure 13 is a plot of more than 3000 mainbeams for the 31 interrogators at 2M+ for the 10 minutes following the measurements at 2M+, extrapolated from scan periods measured at the start.   Jedburg (-), Patrick (o) and Whitehouse (.) mainbeams are marked.   MB's were plotted as 1 vertical division (Mayport was plotted twice as high).   Some attempt was made to let the widths be proportional to the number of interrogations on them.   The unchanging scan periods simulate a situation that aircraft hovering at 2M+, or aircraft entering 2M+ in the next 10 minutes would observe.

Appendix A calculates the probabilities of being interrogated by exactly 0, exactly 1, exactly 2, etc., of the 31 "average" interrogators, i.e., multiple mainbeam coincidences are calculated.   Figure 13 is shown partly for comparison with the calculated probabilities, even though higher order coincidences are more and more exaggerated in it.   It is felt that flights executed on other days, as well as measurements made in the 90-95 percent "off" time of the AMF would have produced "worst" cases every bit as bad as the figure.

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## 6.12  Predicted Mainbeam Coincidence for ARSR's

Even though the relative positions of the mainbeams of the three interrogators marked in Fig. 13 remain almost unchanged in the figure, we know that some time in the future they will overlap in pairs. We used the time positions of the mainbeams and the scan periods of the interrogators to calculate (a) the time-to-go to these coincidences, (b) their durations, and (c) their periods of recurrence. These turned out to be:

| | | Jedburg/Patrick Overlap | | Whitehouse/Patrick Overlap | |
|---|---|---|---|---|---|
| | | Scans | Time | Scans | Time |
| (a) | Time to Go | 292 | .967 hours | 455 | 1.517 hours |
| (b) | No. Partially Jammed MB's (Duration) | 29 | 5.77 min | 50 | 10.03 min |
| (c) | Period of Recurrence | 1602 | 5.348 hours | 2592 | 8.649 hours |
| | Percent Partially Jammed MB's (b/c) | 1.8 | | 1.9 | |

The large number of partially jammed mainbeams (29 and 50) has disturbing implications, especially for a pair of en-route interrogators having primary and secondary surveillance responsibilities for a given area. The extended length of "synchronous jamming" makes the interrogators involved vulnerable to "pop-up" military interrogators as well as other synchronous jammers.

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## 6.13 FAA and AMF Coverages Compared

A comparison of FAA magnetic tape recordings of target data for Jedburg, Aiken, Whitehouse and Valdosta showed an almost 100 percent agreement between AMF visibility at the ground interrogators ("ground coverage"), and visibility of the same interrogators in AMF recordings ("airborne coverage").

## 6.14 The Cause of Missing Target Reports

Missing target reports at an FAA interrogator usually mean no visibility of that interrogator at the AMF either, because of low received power below the AMF threshold, due to sub-marginal propagation. For those locations where AMF visibility exists without FAA visibility, the AMF consistently:

o Received marginal power in the -70-75 dBm range;

o Finds fewer interrogations than on neighboring MB's;

o Has (almost) complete mainbeams missing.

Missing target reports are consistently due to marginal uplink propagation.

## 6.15 Probability of Multiple Interrogations at Loc. 2M+

After dividing the wide-beamwidth, high-sidelobe Mayport NS into two interrogators, some multiple mainbeam coincidence probabilities of degree X were calculated in the presence of N=32 interrogators, each with average interrogation probability $p = 0.0183$, using the Binominal Distribution for a model. The probabilities of exactly 0, exactly 1, exactly 2, etc., interrogations at a given time turned out to be:

$P(0) = .55$      $P(1) = .33$      $P(2) = .0954$

$P(3) = .0178$      $P(4) = .00204$      $P(5) = .000251$

These probabilities may be read from Fig. B-2 (which gives a plot of some 16 probabilities for all values of N), near the right hand edge of the figure, at N=32.

The addition of military interrogators without SLS (contributing 100 percent of a normal PRF) is to change all the labels for the complexity upwards by one without changing the calculated values, i.e., making such multiple mainbeam coincidence more likely.

## 6.16  Probability of Synchronous Jamming at Loc. 2M+

Figure B-1 of Appendix B shows incremental scan periods for 23 (8 + 7 + 8) interrogators at location 2M+ which undergo synchronous jamming of different degree around three popular scan periods (3.925 sec, 4.70 sec, 12.015 sec).  Since the duration of synchronous jamming is inversely proportional to the differences in scan period, and since some of the scan differences in the figure are almost zero, it is evident from Fig. B-1 that some of these durations are quite long.

Maximum durations of sychronous jamming for the three groups are 1.24 hours, 15.57 min, 1.71 hours.

The corresponding repetition periods are:  122 hours, 12 hours, 150 hours.

Minimum durations of synchronous jamming are usually trivially short: 5.3 sec, 26 sec, 54 sec.

The corresponding (brief) repetition periods are:  9.65 min, 17.0 min, 54.7 min.

The ratios of maximum to minimum repetition periods are:  760, 42, 164.

## 6.17  Average Duration of Synchronous Jamming

Figure B-1 shows that average dwell time for the 23 interrogators shown there turns out to be 1 percent of a revolution (corresponding to a beamwidth of 3.6 deg).  We also pick a reasonable average scan difference of 0.1 percent of the scan period, whatever the scan period.

Using these, we arrive at an average duration of partially jammed mainbeams of 2 percent.  The corresponding double-PRF jamming, which is the quantity of concern to us, is 1 percent.  The averge number of partially jammed mainbeamns is 20, and the average number of completely jammed mainbeams is 10, whatever the actual scan periods may be.

For two interrogators on the same scan, but of different beamwidths, double PRF jamming depends on the wider beam (it equals the wider beamwidth, if that is expressed not in degrees, but in fractions of a revolution).

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6.18  Synchronous Or Random Jamming-All Degrees (Fig. B-2)

Two kinds of probabilities are plotted in Fig. B-2, which address the following questions:

1.  What is the probability of mainbeam coincidences of different degrees X at arbitrary instants of time, which are completely uncorrelated with the mainbeams of any interrogator ("general" probability)?

2.  What percentage of the mainbeams of a given interrogator undergo synchronous or random jamming of different degrees X at the time of their regular re-occurrence ("special" probability)?

Figure B-2 contains (in addition to a set of curves with the average beamwidths of 0.0183 revolution for the 32 interrogators at location 2M+) five pairs of general and special probability curves of p = 0.01 (the 1 percent beamwidth case). These are the curves separated from each other by 1 interrogator: the special probability curve of one degree greater complexity is plotted just to the right (1 interrogator away) from the general probability curve of one lesser degree of overlap. This expresses the intriguing relationship betwen the two types of probabilities.

Since the relationship is always so simple, the "special" probability curves for the real situation at location 2M+ (the p = 0.0183 case) has not been plotted in Fig. B-2. The reader may visualize these as plotted just one interrogator (1 N) to the right of the general probability curves of one degree lower complexity.

The reader may find it surprising as did the author that the very low probability general multiple mainbeam coincidences are accompanied by synchronous (or random) jamming probabilities which are much higher. For example, in the 3.6 deg (p = 0.01) case, the percentages of the mainbeams of some interrogator experiencing synchronous (or random) jamming are 10 to 100 times greater than are general mainbeam coincidence probabilities of the same order. This is the whole "raison d'etre" for the definition of the special probabilities. We repeat the definitions given earlier (where P is the underlying interrogation probability, x is the degree of overlap and n is the number of interrogators):

$$PG(p,x,n) = \binom{n}{x} p^x q^{n-x} \qquad 0 \leqslant x \leqslant n \quad \text{(General)}$$

$$PS(p,x,n) = \binom{n-1}{x-1} p^{x-1} q^{n-x} \qquad 1 \leqslant x \leqslant n \quad \text{(Special)}$$

$$PG(p,x,n) = PS(p,x+1,n+1) \qquad \text{(Relation between the two)}$$

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7.0 CONCLUSIONS

The remainder of this report compares the uplink results measured in the Jacksonville area with similar AMF measurements made earlier in the Los Angeles area and along the Boston-Washington corridor (see Project Reports ATC-81 and ATC-83, referenced on p. 1 of this report). It also addresses some of the problems (target splits, lost tracks and poor coverage, especially near the hand-off points between the Washington-Jacksonville-Miami Air Route Traffic Control Centers) mentioned by FAA personnel before the flight.

## 7.1 Comparison with Earlier Results

ATC-81 reports uplink results gathered while the AMF was flying landings and take-offs at the Los Angeles, Van Nuys and San Diego airports, height above ground varying from zero to 1 nm, much lower altitude than even the first leg at Jacksonville (nominal 10,000 ft). A maximum of 12 to 13 interrogators were seen there at the highest altitudes, accompanied by average pulse, suppression and interrogation rates of 2500, 800 and 160/sec, respectively. These are consistent with the Jacksonville results.

ATC-83 reports uplink results based on measurements made along the East Coast between Boston and Washington at 8500 ft, a flight path which was then essentially re-traced at 17500 ft. Here the length of the flight, its altitude and its purpose were much closer to the Jacksonville flight. The results were also quite similar (Jacksonville results are shown in parentheses for comparison): a total of 68 (59) ground interrogators observed; a maximum of 38 (31) interrogators seen at the same place; pulse rate of 2-4 thousand/sec (about the same, lower far off-shore); variable suppression rate of 140-1400/sec (about the same, lower along the ocean leg); Mode A rate of 30-150/sec, Mode C about half of Mode A, Modes 1 and 2, about half of Mode C (again about the same).

## 7.2 FAA-Reported Problems

Target splits, lost tracks and poor coverage may all be attributed to a single cause: missing transponder replies to an en-route interrogator charged with the responsibility of primary or secondary surveillance for airborne traffic crossing a given area. In the case of the Jacksonville Center, the traffic of concern is the one along the coastal air routes flying from Boston-New York-Washington to Miami.

The missing replies themselves may be due to a variety of circumstances. The most common of these are: (1) a transponder out of sight of the interrogator; (2) received power below threshold because of great distance, low transmitter power or transponder desensitization due to reply rate limiting (RRL); (3) transponder unavailability because of high combined suppression and interrogation rates; (4) more than one interrogator on the same PRI or scan period (including PRI differences small compared to the average duration of suppressions and deadtimes (35 and 60 µs, respectively)). Most of these things get aggravated in the presence of (a) reflections, (b) Mode 4 interrogations, and (c) an unusually large number of interrogators visible at the same time (some without (SLS).

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### 7.2.1 High Concentration of Interrogators

The area around the Jacksonville flight path (Fig. 1) contains one of the highest concentrations of powerful interrogators in the country, due to multiple interrogators (almost all without SLS) at the military sites. The 17 January 1980 ECAC File shows 8 interrogators at Beaufort MCAS, 6 at Cherry Point, 4 at Avon Park, Homestead and Mac Dill AFB's, 3 at Kennesaw, Pope, Shaw and Tyndall AFB's (as well as at Charleston and Savannah), and a set of two at many other places. It lists a total of 126 interrogators at the sites shown in the figure. The 59 interrogators detected by the AMF make up 47 percent of the total. The remaining 69 (all without SLS) were not detected during the flight.

### 7.2.2 Strong Altitude Dependence of Interrogators Seen

The high concentration of interrogators implies strong dependence of the number of interrogators visible on aircraft altitude. The best illustration of this is the fact that the smallest number (8) and largest number (31) of interrogators seen both occurred at the same geographical location (1H and 2M+), at 10,000 and 25,000 ft, respectively. (These locations are only 5 nm apart).

It is possible that a jet airliner cruising at 40,000 ft (nominal visibility 242 nm) along the coastal route of Florida would have been observed by 40-50 ground interrogators on the day of the flight test, 23 May 1979. Considering the relatively high occurrence of sidelobe interrogations and reflections for military interrogators without SLS, this might have produced an unacceptably high probability of interrogations bunching above the 1200 IPS level--causing RRL and transponder desensitization.

A high altitude situation like this could account for some of the FAA's problems, especially if some of the military interrogators are close to the FAA en-route interrogators in PRF (synchronous fruit).

### 7.2.3 Coverage Problems in the Jacksonville Area

South-bound air traffic is handed off by Washington Center to Jacksonville Center just north of location 1A. The traffic is similarly handed off to Miami Center 20 nm south of Ormond Beach. Jacksonville Center, therefore, has primary and secondary surveillance responsibility for flight segment 1A through 1U+.

Figure 1 shows that the FAA en-route interrogators of the area are either located right along the coast (like the Jedburg, Whitehouse and Patrick ARSR's), or are offset from the coast about 100 nm to the west (like the ARSR's at Benson, Aiken, Valdosta and Mac Dill AFB). The result is that the offset ARSR's cannot provide surveillance for air traffic below 6,000 ft (less

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than 100 nm visibility). Similarly, traffic at 5,000 ft (87 nm visibility) is invisible to the en-route system near Myrtle Beach and Savannah, and traffic at 2,500 ft (visibility 60 nm = 1 deg latitude) has extended gaps in coverage at all these places, plus at Daytona Beach (= Ormond Beach), the point of hand-off to Miami. The traffic most effected by these gaps in coverage is general aviation, which, however, is still the bulk of total traffic.

At location 1A, the AMF received marginal power (about −70 dBm) from Jedburg. According to the 17 January 1980 ECAC File, Jedburg transmits half the power transmitted by such en-route interrogators as Aiken, Mac Dill and Patrick (0.76 KW vs. 1.5 KW). Being the only Jacksonville Center en-route interrogator providing coverage at this hand-off point at 10,000 ft, Jedburg should bring its transmitted power up to the 1.5 KW level.

### 7.2.4 The Ormond Beach Problems

Considering average transponder deadtimes and suppression times to equal 60 and 35 µs, respectively, we note that a near-by military interrogator without SLS on an average PRF of 330 IPS will make a transponder unavailable for 2 percent of the time. An interrogator (on average PRF) using ISLS in the vicinity of a transponder, will similarly make it unavailable for 1.16 percent of the time. The unavailabilities generally occur at random times and effect isolated single replies only, but they will deny an en-route interrogator many consecutive replies when the PRF's are close enough.

Based on the above, Figure 2 (showing the highest average suppression rate observed for location 1V (1300/sec)) gives a clue to the problems at Ormond Beach. This suppression rate means an a'priori transponder unavailability of 4.55 percent. Figure 11b shows a 50 µs long instantaneous unavailability of over 7 percent for the same location. The possibility that at jet cruising altitudes of 40,000 ft many more than the 15 interrogators seen at 10,000 ft would have been observed, and the possibility that some of the five interrogators listed for McCoy AFB and Avon Park (all without SLS) might intermittently contribute 100 percent of their sidelobes, indicate the possible magnitude of the problems at Ormond Beach. Note that the five interrogators mentioned (one on a double-PRF of 625/sec) could contribute a total of 1300 Mode A's per sec, exceeding the RRL threshold. Reflections from these interrogators, plus the reception of Mode 4 on the sidelobes of nearby interrogators (Jacksonville NAS, Patrick AFB) and the mainbeams of distant interrogators, add yet another dimension to the possible Ormond Beach problems. Unlisted interrogators at Cape Canaveral (again, without SLS) cannot be completely eliminated from consideration.

Note that the only solution to this problem would be to add regular SLS to all interrogators near Ormond Beach which have no SLS at this time, and to change as many FAA interrogators as possible in that area from ISLS to regular SLS--all those that will not develop reflections as a result of the change.

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## 7.2.5 Synchronous Interference Problems

### 7.2.5.1 Ft. Fisher and Aiken on 241 PRF

At location 1C, where the AMF received 100 percent of the sidelobe of Ft. Fisher (4146 μs PRI = 241.2 PRF), the en-route interrogator Aiken (4135 μs PRI = 241.8 PRF) just 11 μs away in PRI had 5 consecutive replies missing once every 1.56 sec when they occurred in the 60 μs (ave) deadtimes caused by Ft. Fisher interrogations just preceding Aiken interrogations. Air traffic at 40,000 ft would encounter this problem at the additional locations 1A, 1B, 2V, 2W, 2X, 2Y (wherever the Ft. Fisher sidelobes without SLS may be received). The problem is alleviated by about a factor of 30 when Ft. Fisher uses its SLS, which, apparently, is the only solution other than separating the PRI from the current 11 to perhaps 60 μs.

### 7.2.5.2 Ft. Fisher and Mac Dill on 241 PRF

Mac Dill ARSR (4147 μs PRI = 241.1 PRF) has a PRI which is only 1 μs different from Ft. Fisher. Mac Dill would have 60 of its replies missing in a row (lasting for 0.25 sec) once every 17.20 sec, if it were seen together with Ft. Fisher by high-flying air traffic. Since Ft. Fisher was observed outside nominal visibility of 125 nm at 10,000 ft at locations 1H, 1I and even at 1U, it is probably so favorably located and so powerful as to be visible to coastal traffic at 40,000 ft all the way to Jacksonville and even at the problem area of Ormond Beach, although with a narrow beam under 1 percent. Assuming an equally narrow beam for Mac Dill would seem to make this interference statistically insignificant, if it were not for the identical scan periods for the two, implying many mainbeam coincidences in a row followed by extremely long absence of coincidences. The way this would work is strong interference (perhaps complete mainbeams missing) for a relatively short interval of some minutes followed by freedom from interference for many hours of even days.

### 7.2.5.3 Benson and Valdosta on 370 PRF

Benson and Valdosta are on identical PRF's of 370.3. Hundreds of their interrogations will overlap whenever they get in phase. They will interfere about the same way as Mac Dill and Ft. Fisher above, with the following differences: (1) both of them are FAA en-route interrogators; (2) their scan periods are different; and (3) they are closer, and, presumable, have more overlap in coverage. Coastal traffic at 40,000 ft in the Charleston -Beaufort area would be most effected.

### 7.2.5.4 Maiden and Patrick on 360 PRF

Maiden (2778 μs PRI = 359.9 PRF) and Patrick (2776 μs PRI = 360.2 PRF), two en-route interrogators on 5-pulse stagger, have a 2 μs difference in PRI, which eliminates 30 replies in a row for either of them, when they interrogate in the deadtimes caused by the other one. Like Ft. Fisher and Mac Dill, they are on identical scans. Fortunately, only a small segment of the 40,000 ft coastal traffic near Savannah can see both of them. An out-of-phase stagger is some help near the ends of the deadtimes.

### 7.2.5.5 Jacksonville NAS, Panama City and Richmond on 355 PRF

Jacksonville NAS (2819 µs PRI = 354.7 PRF) is on a PRI which is halfway between the 2 µs separated PRI of Panama City (1818 µs PRI = 354.9 PRF) and Richmond (2820 µs PRI = 354.6 PRF). Jacksonville NAS will therefore interfere with 60 consecutive replies of both of these en-route interrogators. Jacksonville is an unusually powerful and wide beam interrogator with regular SLS, permitting many sidelobe interrogations and reflections out to 100 nm. In addition, it uses Mode 4 liberally, which alone will produce 5 or 6 percent transponder unavailability (see Sec. 3.8) for interrogators on random PRI. For Panama City and Richmond, Mode 4 from Jacksonville NAS becomes synchronous suppression of (possibly) 100 replies in a row from transponders in the larger Jacksonville area. This interference may last 0.282 sec, and it has 1 chance in 28 of happening with the random use of Mode 4.

The AMF observed Panama City well beyond nominal visibility at location 2M+, indicating that this interrogator might be able to see 40,000 ft coastal traffic from Savannah to Ormond Beach. Richmond probably picks up this same traffic somewhere between Jacksonville and Ormond Beach.

Synchronous interference from Jacksonville NAS contributes to the Ormond Beach problems. The solution again is a change of PRF's. Keeping other PRF's in the area in mind, a possible choice would be to put Panama City on a PRI of 2798 (357.4 PRF), and Richmond on a PRI of 2841 µs (352.0 PRF). The resulting plus/minus 21 µs differences from Jacksonville NAS would alleviate the interference problem by more than an order of magnitude.

### 7.2.5.6 Synchronous Interference for Terminal FAA Interrogators

There are some FAA terminal interrogators on near-identical PRF's in the Jacksonville area. These are not part of the en-route system, and the interference effects only their local traffic. Many of these were observed at more than 100 nm at 10,000 ft. Their almost exclusive use of ISLS means that the majority of the interference will probably occur in the 35 µs suppression times rather than in the deadtimes. Note that close-by traffic may receive suppressions up to 99 percent of the PRF's. The number of missing replies (mr's) in a row (given in parantheses below) will be those due to synchronous suppressions. For the rarer cases of synchronous interrogation deadtimes on the mainbeams, these must be multiplied by a factor of 1.7.

The northernmost pair of interfering ASR's are Charlotte and Fayetteville on a PRF of 381. PRI difference = 1.8 µs (19 mr's). Visibilities extend down to Savannah. Orlando on the same PRF is too far to be a problem.

Daytona Beach and Sarasota on 390 and 391 PRF's have a 4.3 µs PRI difference (8 mr's). Visibilities extend from Jacksonville to Miami. Charleston on the same PRF is too far to be a problem.

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Tallahassee and Robins AFB on 400 PRF have a PRI difference of 2.3 μs (15 mrs). Visibilities extend to Jacksonville.

Augusta ASR on 395 PRF and the military interrogator at Jacksonville, NC have a PRI difference of 1 μs. Since this interrogator does not use ISLS, and since the interrogators are far from each other, the synchronous interference is minimal in this case.

# APPENDIX A

## LIKELIHOOD OF MULTIPLE INTERROGATIONS AT LOC. 2M+

### 1.0 Probabilities of Multiple Interrogations

It is useful to calculate P(0), P(1), P(2), P(3), etc., the probabilities of being interrogated by exactly 0, exactly 1, exactly 2, etc.,interrogators, given the common probability p of being interrogated by any one of them.

The Binomial Distribution, P(x), is to be used for a probability model. P(x) represents the probability of realizing an event exactly x times (receiving exactly x interrogations) in n independent repeated trials (from n interrogators), such that the probability of success in each trial is given by p. This is done even though the scan-to-scan independence of our interrogators is far from ideal. The Binomial Distribution for P(x) is given by;

$$P(x) = \binom{n}{x} \cdot p^x \cdot q^{n-x} \quad (0 < p \leq 1; \ x = 0,1,2,\ldots,n)$$

where;

$$\binom{n}{x} = \frac{n!}{x! \, (n-x)!} \quad x = 0,1,2,\ldots \leq n = 0,1,2,\ldots,32$$

is the binomial coefficient.

### 2.0 Probability of Exactly x Interrogations

Substituting (from Sec. 4.2.1) p = 0.0183, q = 0.9817 and n = 32, as per the real-world situation, into the Binomial Distribution, the desired probabilities of being interrogated by exactly 0, exactly 1, exactly 2, etc., of our 32 average interrogators, are given by:

$$P(0) = \binom{32}{0} p^0 q^{32} = 0.5538$$

$$P(1) = \binom{32}{1} p^1 q^{31} = 0.3303$$

$$P(2) = \binom{32}{2} p^2 q^{30} = 0.0954$$

$$P(3) = \binom{32}{3} p^3 q^{29} = 0.0178$$

$$P(4) = \binom{32}{4} p^4 q^{28} = 2.0405 \times 10^{-3}$$

## 3.0 Mainbeam Coincidence Interpretation

Another way of interpreting the probabilities P(x) (x = 0,1,...,32) calculated above is to look at (independent) instants of time, and ask for the probability of 0, 1, 2, 3, etc., mainbeams of our 32 interrogators (with their different scan periods) coinciding at each instant of time, causing multiple interrogations of the same degree there. We realize that although the relative pointing of the 32 interrogators is quite random at a given instant, their fixed scan periods make them predictable for all future time.

## 4.0 P(I) - Probability of "Being Interrogated"

Note that the probability P(I) of being interrogated by either 1 or 2 or 3,...., or 32 interrogators at some instant is given by the sum of the probabilities P(1) + P(2) + P(3) + ... + P(32). P(I) can be calculated:

$$P(I) = 1 - P(0) = 0.4462$$

## 5.0 Probability of More Than x Interrogations

The probabilities of being interrogated by 2 or more, 3 or more, etc., interrogators (denoted here by P(2+), P(3+), etc.) are given by the differences

$$P(2+) = P(I) - P(1) = 0.1159$$

$$P(3+) = P(2+) - P(2) = 0.0204$$

$$P(4+) = P(3+) - P(3) = 0.00269$$

$$P(5+) = P(4+) - P(4) = 0.000274$$

In general,

$$P(N+) = P(I) - P(1) - P(2) - P(3) - ... - P(N-1)$$

gives the probability of being interrogated by N or more interrogators at the same time (or, alternately, the probability of N or more mainbeam coincidences).

## 6.0 Summary of Multiple Interrogation Probabilities

It is clear from the above that at location 2M+, in the presence of 32 (actually 31) interrogators with average beamwidths of 6.59 deg., the probability of not being interrogated (P(0) = 0.55376) exceeds the probability of being interrogated (P(I) = 0.44624) by 24 percent only. The fact that these two events are almost equally likely is of some interest.

A list of probabilities follows, including (in parentheses) the average number of trials needed to realize the events once.

$P(0) = 0.5537$       (1.8)

$P(1) = 0.3303$       (3)       $P(I) = 0.44624034$       (2.2)

$P(2) = 0.0954$       (10)       $P(2+) = 0.1159137$       (9)

$P(3) = 0.0178$       (56)       $P(3+) = 0.20246994$       (49)

$P(4) = 2.40 \times 10^{-3}$       (416)       $P(4+) = 2.678143 \times 10^{-3}$   (373)

$P(5) = 2.51 \times 10^{-4}$       (3984)       $P(5+) = 2.73613 \times 10^{-4}$   (3655)

$P(6) = 2.10 \times 10^{-5}$       (47492)

$P(7) = 1.46 \times 10^{-6}$       (685926)

## 7.0 Effect of Addition of Interrogators Without SLS

It is likely that a number of military interogators without SLS were not discovered during the Jacksonville flight for two reasons: (1) they were never turned on, since they were not part of the military operations on the day of the AMF flight, or (2) they operated in short bursts only during the 90 percent of total time not recorded by the AMF. Interrogators like these can contribute 100 percent of their PRF's to the ambient interrogation environment (as Ft. Fisher did at location 1A). So it is important to ask how the probabilities calculated above would have changed if, one or two of these had been turned on during the few unrecorded minutes just before or just after the recording at 2M+.

One interrogator of this nature (on an average PRF) would change P(1) and P(I) from their currect values of 0.330 and 0.446 to 1 since the AMF would be interrogated all the time. It would also shift all calculated probabilities by one level of complexity. P(2) would take on the current value of P(1) etc).

Two such interrogators would make P(1)= P(2)= P(I)= 1. They would also shift all the calculated probabilites by two levels of complexity.

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# APPENDIX B

## LIKELIHOOD OF SYNCHRONOUS OR RANDOM JAMMING

### 1.0 Synchronous Jamming at Location 2M+

#### 1.1 Introduction to Figure B-1

Figure B-1 shows a plot of 23 (= 8 + 7 + 8) incremental scan periods for selected interrogators at 2M+, grouped around 3.93, 4.70 and 12.01 seconds. The three heavy vertical arrows in the figure show 1 percent differences in scan period for each group. Interrogator numbers and names are shown at the bottom of each part.

Dwell times (in ms) are given at the top of the figure. From this, three average dwell times are calculated to show that these are approximately 1 percent of the scan periods, regardless of the lengths of the scan periods. From all this, the duration of synchronous jamming (continued mainbeam coincidences), and their frequencies of occurrence may be estimated.

#### 1.2 Synchronous Jamming Defined

When the probability of occurrence of mainbeam coincidences was discussed and calculated in Appendix A, it was based on isolated ("random") events, independent from each other. These were not cases of synchronous jamming.

By definition, synchronous jamming refers to the gradual approach, long overlap and slow separation of the mainbeams of two interrogators with almost equal ("synchronous") scan periods. The word "jamming" describes the interrogations on double PRF occurring during the overlapping portion of the mainbeams, which can last at most as long as the shorter of the two dwell times involved. If there are K interrogators with near-equal scan periods, higher order synchronous jamming (all the way to degree K) will occur with lower and lower probability. Each occurrence of double-, triple-, and higher-PRF interrogation is limited to the shortest dwell time, while its overall probability is determined by the longest dwell time.

An examination of the scan periods of the 31 interrogators seen at 2M+ reveals the presence of 23 interrogators with near-equal scan periods there. These can cause significant synchronous jamming in the sense defined above, in groups of 8, 7, and 8, spread in three tight bands around the scan periods 3.925, 4.70, and 12.015 sec, respectively. These are exactly the interrogators shown in the three parts of Figure B-1.

A calculation of the longest (Tmax) and shortest (Tmin) duration of synchronous jamming for the three groups, as well as the repetition time (period) (Pmax, Pmin) of the occurence of such jamming follows in the next three sections. As long as these durations and periods are measured in "scans", there is no reason to expect differences between the groups, for the average dwell time is about 1 percent for each, corresponding to a 3.6 deg beamwidth, regardless of scan period.
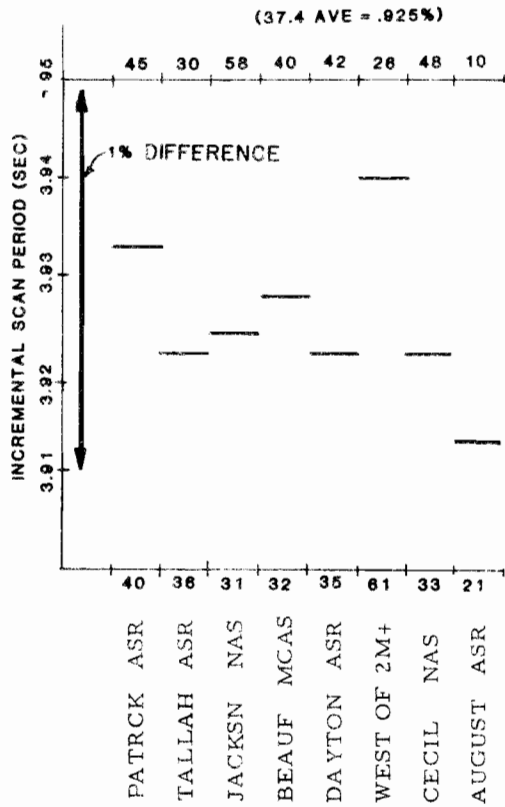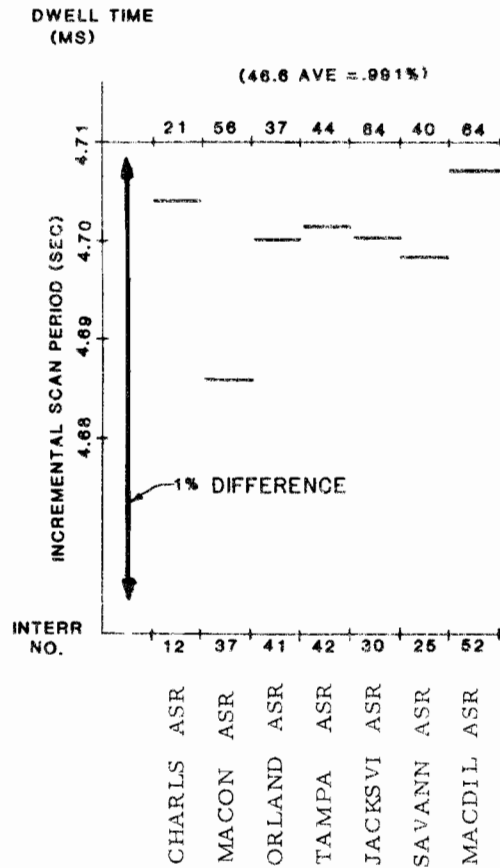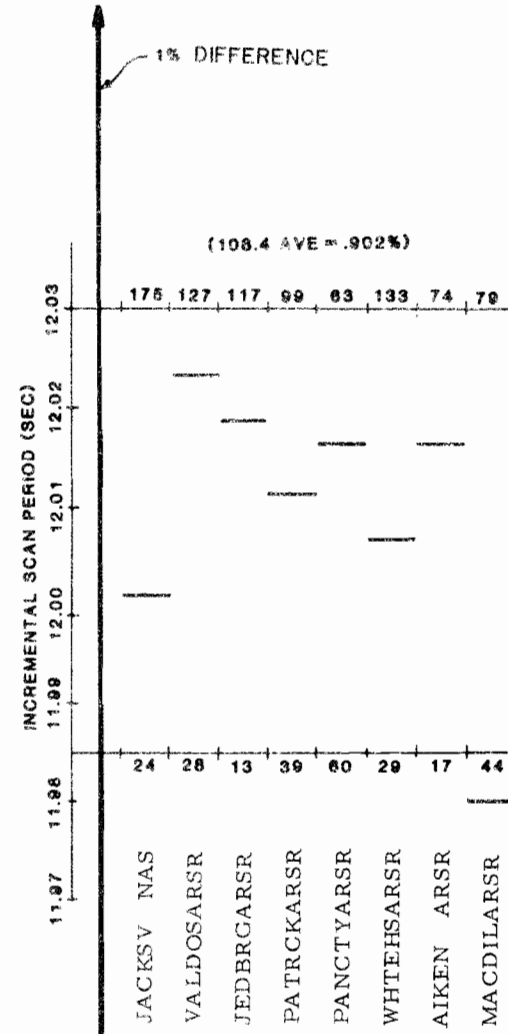
Incremental Scan Periods for 23 of the 31 Interrogators Seen 23 NM East of Whitehouse ARSR (Loc. 2M+) Grouped around 3.925, 4.70 and 12.015 Second Scans. Dwell Times And Their Averages (MS And Percent Scan) Are Shown at the Top, Interrogator No's And Names at the Bottom. Heavy Vertical Arrows Show 1% of a Scan Period for Each Group to Scale.

Figure B-1

### 1.3 Synchronous Jamming on 3.925 - Second Scan

The durations (T) are given by the sum of the dwell times W1 + W2 (=L12) divided by the positive scan differences S1-S2 (=DS12). Similarly, the repetition periods (P) are given by the shorter scan period (S2) divided by the positive scan differences S1-S2. The small variations in the numerators of these expressions are occasionally completely overshadowed by the near-zero denominators. This is the case when looking for TMax and Pmax among the 8 interrogators on 3.925-sec scan.

Interrogators 33, 35, and 36 (Cecil, Daytona Beach, and Tallahassee) show almost equal scans. Daytona Beach minus Tallahassee is actually smallest (DS12 = 0.000035 sec, L12 = 0.072 sec, S2 = 3.922011 sec), thus:

Tmax = L12/DS12 = 2057 scans = 8074 sec = 134.57 min = 1.2428 hours

Pmax = S2/DS12 = 112057 scans = 439826 sec = 7330 min = 122.174 hours,
= 5.09057 days

Tmin and Pmin will be determined from the greatest difference in scan periods. Interrogator 61 minus interrogator 21 (Augusta) gives DS12= .026540 sec, L12 = 0.036 sec, S2 = 3.913122 sec. From these:

Tmin = L12/DS12 = 1.3564 scans = 5.324 sec

Pmin = S2/DS12 = 147.44 scans = 579 sec = 9.65 min

Pmax/Pmin = 439826/579 = 760

Pmax and Pmin have the very large ratio of 760.

### 1.4 Synchronous Jamming on 4.70 - Second Scan

Interrogators 30 and 41 (Jacksonville International and Orlando) turn out to have the smallest scan difference among the 7 interrogators of this group. We have DS12 = 0.000508 sec. L12 = 0.101 sec., S2 = 4.700131 sec., thus:

Tmax = L12/DS12 = 198.82 scans = 934 sec = 15.574 min

Pmax = S2/DS12 = 9252 scans = 43485 sec = 724.76 min = 12.0793 hours

Shortest jamming (Tmin and Pmin) comes from the largest scan difference. Interrogator 52 (Mac Dill) minus interrogator 37 (Macon) gives DS12 = 0.021555 sec, L12 = 0.120 sec, S2 = 4.685730 sec. From these

Tmin = L12/DS12 = 5.5672 scans = 26.16 sec

Pmin = S2/DS12 = 217.385 scans = 1022 sec = 17.028 min

Pmax/Pmin = 43485/1022 = 42

## 1.5 Synchronous Jamming on 12.015 - Second Scan

Interrogators 17 and 60 (Aiken and Panama City) have the smallest scan difference among the 8 interrogators of this group. Aiken minus Panama City gives DS12 = 0.000267 sec, L12 = 0.137 sec, S2 = 12.01628 sec, thus:

Tmax = L12/DS12 = 513.1086 scans = 6165 sec - 102.75 min = 1.7125 hours

Pmax = S2/DS12 = 450 scans = 540733 sec = 9012 min = 150.2035 hours = 6.25848 days

Shortest jamming (Tmin, Pmin) comes from the largest scan difference. Interrogator 28 (Valdosta) minus interrogator 44 (Mac Dill) gives DS12 = 0.043840 sec, L12 = 0.206 sec, S2 = 11.979537 sec. From these:

Tmin = L12/DS12 = 4.699 scans = 56.46 sec

Pmin = S2/DS12 = 273.256 scans = 3283 sec = 54.7195 min

PMax/Pmin = 540733/3283 = 164

Synchronous jamming lasting for 1.7 hours is perhaps an estimate of "worst of the worst" case. Still, things like this could occur, but their more likely mechanism might be the "wandering back and forth" of the mainbeams of two far-away enroute interrogators such as the Aiken and Panama City ARSR's.

## 1.6 Average Duration of Synchronous Jamming

Earlier it was noted that the average dwell time for the three groups of interrogators shown in Figure B-1 was about 1 percent (corresponding to a 3.6 deg beamwidth) regardless of scan period. It is now assumed that this is true for all interrogators in the figure. In addition, let us pick a reasonable average scan difference of 0.1 percent of the scan period for all three groups. (This means one-tenth of the 1 percent line for each case in the figure).

These assumptions result in the following average values for the duration (TAve) and the repetition period (Pave) of synchronous jamming (mainbeam coincidence) at location 2M+:

Tave = 20 scans (Double PRF: 10 complete mainbeams; see below)

Pave = 1000 scans

Tave/Pave = .02 (2 percent)

(= 1 percent, Double PRF Jamming)

The 20 scans (mainbeams) partially effected by double PRF jamming represent 78.5, 94.00, and 240.3 sec of real time, depending on the scan periods involved. Similarly, the 1000-scan average repetition period represents 3925, 4700, and 12015 sec (or 65.417, 78.333, and 200.25 min, or 1.0903, 1.3055, and 3.3375 hours) of real time, depending once again on the scan periods.

### 1.7 Double PRF Jamming (1 Percent Average)

Double PRF jamming occurs only during the overlapping portions of the mainbeams. Therefore (for the above average parameters), its length increases linearly by 1/10-th of the widths of the mainbeam (1/1000-th of the scan period) from one mainbeam (scan) to the next one until complete separation.

Thus overlaps last for 0.36, 0.72, 1.08,..., 3.24, 3.60, 3.24, ..., 1.08, 0.72, 0.36, 0 degrees for all interrogators in Figure B-1. These numbers add to 36 degrees (10 mainbeams) for each complete event of synchronous jamming (repeating itself after 1000 scans). Dividing the 10 mainbeams by 1000 scans gives PSJ2 = .01 for the probability of average mainbeam-to-mainbeam synchronous jamming between any two interrogators in Figure B-1 (both chosen from the same group).

## 2.0 Synchronous Jamming Probabilities

### 2.1 Results at Location 2M+ Generalized

Synchronous jamming occurs at any location where at least two interrogators on near-identical scan are interrogating the same airborne transponder. The 1 percent value for PSJ2 (second order synchronous jamming probability) is probably also typical, since it corresponds to a beamwidth of 3.6 deg.

The companion probability QSJ2 = 1 - PSJ2 represents the 99 percent of the mainbeams of an interrogator free from synchronous jamming by another interrogator on the same scan.

For a pair of interrogators with equal beamwidths (BW1 = BW2) (and near-equal scan period), the probability of synchronous jamming is always given by PSJ2 = BW1 = BW2, as long as the beamwidths are measured not in degrees but in fractions of a scan (fractions of a revolution).

## 2.2 The Case of Un-Equal Beamwidths

Assume that BW1 < BW2 (in scans, again) and that the scan difference (Sdif, measured in scans) still equals .001, as above. What happens then is that the faster mainbeam of the interrogator with the larger scan period catches up with, overlaps and then clears the mainbeam with the smaller scan period, regardless of which is the narrower of the two (called BW1 above). We want to determine the number of completely jammed mainbeams (NJ), which is given by the number of complete overlaps (NCO) plus half the number of partial overlaps (NPO). These are given by:

NCO = (BW2 −BW1)/Sdif

NPO = 2 X BW1 / Sdif

NJ = NCO + NPO/2 = BW2 / Sdif

The desired jamming probability (PSJ2) is just the ratio of completely jammed mainbeams (NJ) to total mainbeams in one period of synchronous jamming (PER). Note that PER is also the number of scans in a period, and it is given by PER = 1/Sdif when everything is measured in scans. The result is, that for interrogators with different beamwidths, synchronous jamming probability is given simply by the wider of the two beamwidths (BW2) (expressed in "scans"):

PSJ2 = NJ / PER = NJ X Sdif = BW2 (in scans)

As an example, consider an interrogator with 3.6 deg beamwidth causing synchronous jamming to another one with 4 X 3.6 = 14.4 deg beamwidth with a scan difference of 1/10 of 1 percent. Measured in scans, we then have BW1 = 0.01, BW2 = 0.04, PER = 1/Sdif = 1000, and

NCO = (0.04 −0.01) /0.001 = 30

NPO = 2 X .01 / .001 = 20

NJ = NCO + NPO/2 = 30 + 10 = 40

PSJ2 = 40 / 1000 = 0.04 (4 percent Double PRF Jamming)

QSJ2 = 1 −PSJ2 = 0.96 (96 percent Clear Mainbeams)

## 2.3 The case of Arbitrary Scan Differences

A scan difference (Sdif) of 0.001 scans was assumed in the above calculations of synchronous jamming probabilities PSJ2. It will now be shown that they do not depend on the scan differences at all (i.e., their dependence cancels out.)

Recall that NJ (the number of completely jammed mainbeams) was given by BW2/SDif; PER (the number of mainbeams or scans in a period) was given by 1/SDif; and that the jamming probability is given by the ratio PSJ2 = NJ/PER = (BW2/SDif)/(1/SDif), where the scan differences obviously cancel.

The only effect of arbitrary scan differences is to lengthen or shorten both the overlap time and the period of synchronous jamming by equal factors, which still leaves the jamming probability PSJ2 depend only on the wider of the two beamwidths involved (BW2, measured in fractions of a scan).

## 3.0 Synchronous Or Random Jamming

### 3.1 Introduction to Figure B-2

Figure B-2 shows 16 probability curves to be discussed below. The horizontal scale is n, the number of interrogators seen by the AMF (or any other airborne transponder) at location 2M+ or at some other location with "typical" uplink conditions.

The vertical scale represents probabilities on a logarithmic scale in the range 0.0001 to 1.0, which can also be interpreted as percentages (of, say, mainbeams jammed) in the range .01 to 100 percent.

Eleven of the curves give "general" probabilities ("PG", see below), and the remaining five give "special" probabilities ("PS", again, see below). One set of curves uses basic (average) interrogation probability of p = .0183, the other two sets (of five each) use p = .01 (1 percent). These ten curves serve as handy reference curves for other probabilities above and below 1 percent, but, more than that, they are also quite "typical" for the many locations where uplink interrogator beamwidths average 3.6 deg (1 percent of a revolution).

Different members of each set of curves correspond to increasing degrees x of mainbeam coincidences. Each curve gives the probability of being interrogated by exactly x interrogators, and not being interrogated by the remaining n −x of the total interrogator population n. The probability of not being interrogated by any of the n interrogators (probability of being interrogated be exactly 0 of them) occurs when x = 0.

108
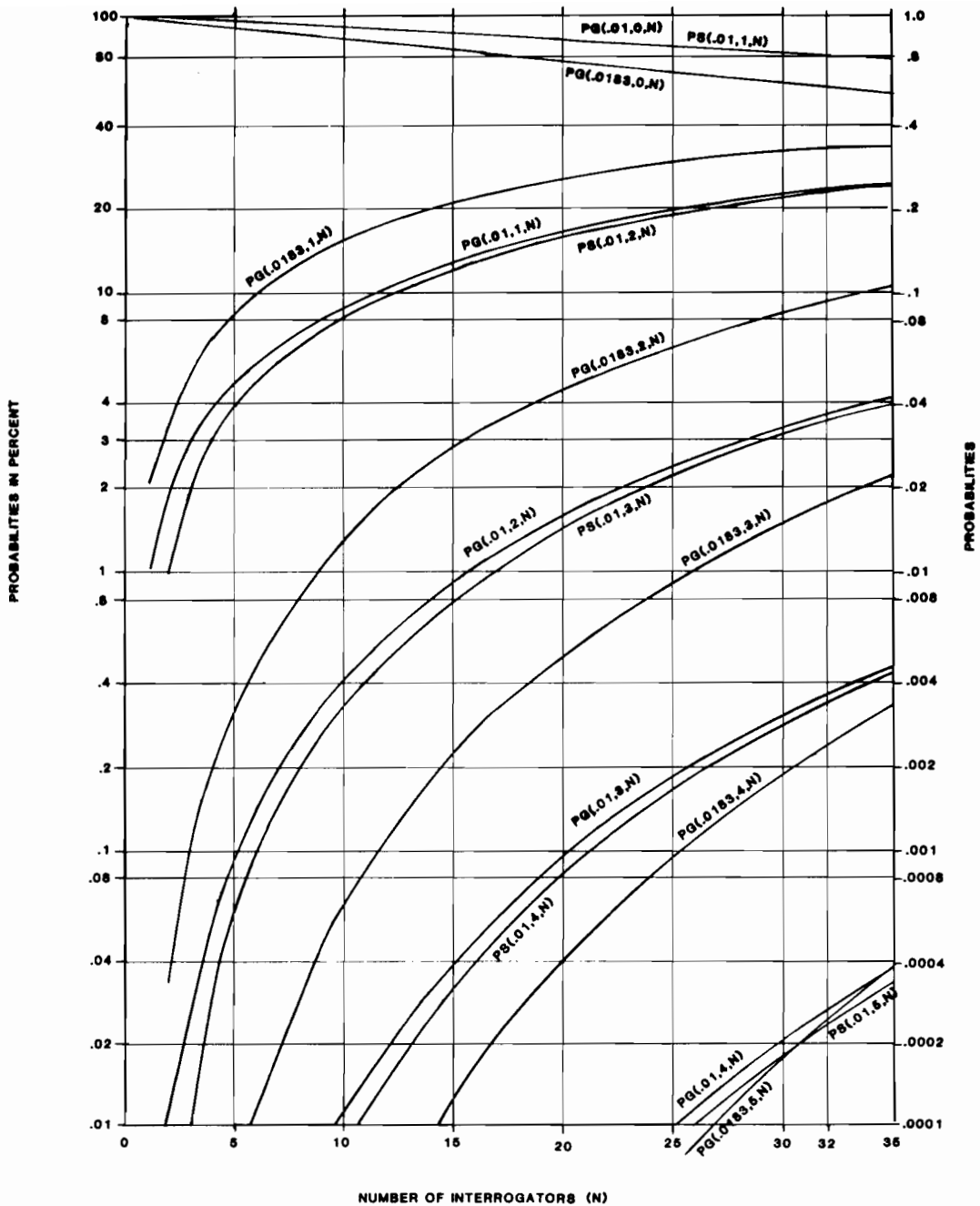
"GENERAL" AND "SPECIAL" PROBABILITIES OF MULTI-PRF JAMMING
(MAINBEAM COINCIDENCES) (PG(P,X,N) AND PS(P, X, N)
(P: (AVE) BASIC PROB; X: DEGREE; N: NO. OF INTERROGATORS)
(P = .0183, N = 32 REFERS TO LOC. 2M + , 23 MAY 1979 JACKSONVILLE FLIGHT, AMF)

Figure B-2

## 3.2 "General" and "Special" Jamming Probabilities

Considering either synchronous or random jamming, two different questions may be asked:

> (1) What is the probability of mainbeam coincidences of different degrees x at arbitrary instants of time, uncorrolated with the mainbeams of any interrogator ("general" probability)?

> (2) What percentage of the mainbeams of a given interrogator undergo synchronous or random jamming of different degrees x at the time of their regular re-occurence ("special" probability)?

The following expressions define "general" and "special" probabilities:

$$PG(p,x,n) = \binom{n}{x} p^x q^{n-x} \qquad 0 \leqslant x \leqslant n \qquad \text{(General)}$$

$$PS(p,x,n) = \binom{n-1}{x-1} p^{x-1} q^{n-x} \qquad 1 \leqslant x \leqslant n \qquad \text{(Special)}$$

$$PG(p,x,n) = PS(p,x+1,n+1) \qquad \text{(Relation between the two)}$$

The "general" probability $PG(p,x,n)$ applies as follows. When n interrogators with identical individual probabilities of interrogation p are present, this is the probability that exactly x are looking at an aircraft, and n-x are not looking. The number of ways this can happen is given by the binomial coefficient $\binom{n}{x}$, specifying the number of different ways one may select x interrogators out of a total population of n. Since each of the $\binom{n}{x}$ configurations defines a component (event) which is disjoint, the components may be summed to obtain the complete probability of being interrogated by any x of the n interrogators.

The changes observed in the expression for the "special" probability $PS(p,x,n)$ are due to a number of factors. First of all, one of the basic probabilities p must be changed to 1, since the interrogator whose mainbeams we focus on is now certain to interrogate. At the same time, the exponent of p must be reduced by 1 (from x to x-1), since one less interrogator is needed to point at an aircraft for any degree of overlap.

Picking a set of mainbeams not only increases the overlap by one degree of complexity, but also eliminates one of the interrogators remaining to be chosen. The binomial coefficient must be changed from $\binom{n}{x}$ to $\binom{n-1}{x-1}$ to reflect the change.

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### 3.3 "General" and "Special" Probabilities Compared

The third equation above relating the two types of probabilities defined by the first two equations indicates that (for the same base probabilities p) the "general" probability "PG" of mainbeam overlaps of some degree x, in the presence of n interrogators equals the "special" probability "PS" of one degree higher overlap x+1 in the presence of one additional interrogator n+1.

This relationship is very clear in Figure B-2 where each special probability curve of degree x is displaced from a general probability curve of degree x-1 by the space of a single interrogator (is plotted to the right by 1 division in n). Five special probability curves are plotted in this figure for the 1 percent base probability case (p = 0.01), given by the first five members of

$$PS(.01,x,n) = \binom{n-1}{x-1} .01^{x-1} .99^{n-x} \qquad 1 \leqslant x \leqslant n \text{ (Special)}$$

These may be seen to be displaced to the right by 1 n (one interrogator) from the five companion general probability curves given by the first five members of

$$PG(.01,x,n) = \binom{n}{x} .01^{x} .99^{n-x} \qquad 0 \leqslant x \leqslant n \text{ (General)}$$

The other six general probability curves in the figure use for their base probabilities the "effective" beamwidths of 1.83 percent (p = .0183) (calculated in Section 4.2.1 of the body of this report) to include all sidelobe interrogations present at location 2M+. These are given by;

$$PG(.0183,x,n) = \binom{n}{x} .0183^{x} .9817^{n-x} \qquad 0 \leqslant x \leqslant n \text{ (General)}$$

Note that the companion special probability curves (percent mainbeams jammed) have not been plotted in Fig. B-2 for the six p=.0183 general probability curves. The reason is that these may be easily estimated for any X and N from the value of the general probability for (X-1) and (N-1).

For example, the percentage of mainbeams of an interrogator experiencing third degree jamming (X=3) in the presence of ten interrogators (N=10) is about 1 percent, as it is read from the PG(.0183,2,N) curve at N=9, which gives the probability of exactly 2 mainbeam coincidences at any instant of time.

### 3.4 Discussion of Figure B-2

Initial points of the general probability curves PG(p,x,n) of Figure B-2 occur when n has the minimum value necessary for the degree of overlap considered. Thus the curves start at n = 0, 1, 2, 3, 4, and 5 for overlaps of degree x = 0, 1, 2, 3, 4, and 5.

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Here $\binom{n}{x}$ has the value $\binom{n}{x} = \binom{x}{x} = 1$, and $q^{n-x}$ has the value $q^{n-x} = q^{n-n} = q^0 = 1$. Therefore initial values of the general probability PG(p,x,n) are given by;

$$PG(p,x,n) = \binom{x}{x} p^x q^{x-x} = p^x \qquad \text{for } x = 0, 1, 2, 3, 4 \text{ and } 5$$

These initial values are tabulated below.

| x = n | $p^x$ | |
|---|---|---|
| | p = 0.01 | p = 0.0183 |
| 0 | 1.0 | 1.0 |
| 1 | 0.01 | $1.8300 \times 10^{-2}$ |
| 2 | 0.0001 | $3.3489 \times 10^{-4}$ |
| 3 | 0.000001 | $6.1285 \times 10^{-6}$ |
| 4 | 0.00000001 | $1.1215 \times 10^{-7}$ |
| 5 | 0.0000000001 | $2.0524 \times 10^{-9}$ |

The sixteen curves plotted in Figure B-2 lie closer to one-another toward the right-hand edge of the figure, as the number of interrogators approaches 35.

4.0 Main Jamming Results at Location 2M+

Figure B-1 shows that about one quarter of the interrogators (8, 7, and 8 out of 32) use near-equal scan periods grouped around the values 3.925, 4.70, and 12.015 seconds, respectively. This means that about one quarter of the total jamming experienced by these interrogators is "synchronous", and three quarters of the jamming is "random". Note that the effects of either type jamming are identical (multiple-PRF interrogations), and the only reason we differentiate synchronous jamming is because it occurs regularly between pairs of interrogators, and because the mainbeams effected are always adjacent ones.

The actual uplink situation at location 2M+ is shown in Fig. B-2 by the vertical line at n=32 interrogators. The special probabilities tabulated below for various degrees of overlap of the mainbeams of a given interrogator have been approximated from the general probability curves PG (.0183) and one less degree of overlap. (They apply exactly for one more (n=33) interrogator.)

| Degree of PRF Overlap | Special Probability | Chances Needed to Realize Once |
|:---:|:---:|:---:|
| 1 | 0.554 | 1.8 |
| 2 | 0.330 | 3 |
| 3 | 0.095 | 10 |
| 4 | 0.018 | 56 |
| 5 | $2.404 \times 10^{-3}$ | 416 |
| 6 | $2.510 \times 10^{-4}$ | 3984 |

The results indicate that every 3rd mainbeam of an interrogator at location 2M+ will on the average have double-PRF jamming, every 10th triple-PRF jamming, every 56th quadruple-PRF jamming. Note that quadruple-PRF usually means over 1300 interrogations/sec. This exceeds the usual threshold (1200 IPS) for reply rate limiting (RRL), therefore it can cause transponder desensitization and possibly track loss.

Note that the special probabilities listed in the results above are identical to the general probabilities PG(.0183,x,32) calculated earlier for overlaps of one degree less complexity. The first line, for example, states that the probability of exactly 1-degree overlap is the same as the probability of not being interrogated (0.554) calculated earlier (Section 4.3.5), when we are already looking at the mainbeam of some interrogator with probability 1.

If we equate RRL with PRF overlap of degree 4, we see that, as far as actual measurements at location 2M+ are concerned, it occurs about 2 percent of the time. Since AMF measurements cover only one day, and even then only 5 to 10 percent of the total uplink, it is quite likely that other days (or even the unmeasured 90 to 95 percent) include pop-up military interrogators on 100 percent PRF (without SLS). One of these would increase RRL probability to 10 percent, two of them, to 33 percent.

Speaking conservatively, we should not rule out even several of these for a "worst case" at 2M+, and should probably include all or part of one even for the "expected" uplink complexity here.

For the three groups of interogators in Figure B-1 which experience synchronous jamming in groups of 7 or 8, a smaller portion of the total jamming is "synchronous". If we assume 1 percent beamwidths for these (as we calculated it above), we may read their synchronous components of degrees 2 and 3 directly from Figure B-2 along the special probability curves $PS(.01,x,n)$ for $x$ = 2 and 3, and $n$ = 7, and 8. Doing this, we find the following values:

| Degree x | No. of Interrogators n | Synchronous Jamming Component |
|----------|------------------------|-------------------------------|
| 2        | 7                      | 0.05706                       |
|          | 8                      | 0.06590                       |
| 3        | 7                      | 0.001441                      |
|          | 8                      | 0.001997                      |

## APPENDIX C

## DEFINITION OF TERMS

The principal figures and tables of the report are generally self explanatory. However, the following definitions clarify the manner in which the uplink data analysis program handles the pulse data recorded in flight.

Interrogations A pair of pulses (P1 and P3) within 0.25 μs of the prescribed separation times for Mode 1, 2, A, C (3, 5, 8 and 21 μs, respectively); P3 amplitude must exceed value prescribed by 3.5 dB/μs desensitization; a P2 pulse not exceeding P1 by more than 3 dB may be present.

Suppressions A pair of pulses (P1 and P2) within 0.25 μs of the prescribed separation time (2 μs) for suppressions and with amplitudes in the range $-3 < P1 - P2 < +3$; a P3 pulse may also be present (3 pulse suppression).

Stray Pulses Pulses that cannot be legitimately associated to form interrogations or suppressions; mostly the powerful P2 pulses of interrogators using regular SLS (transmitted on their onmi-directional antennas); also the reflections of real pulses, TACAN pulses, etc.