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A SURVEY OF AIRBORNE RADAR SYSTEMS FOR DEPLOYMENT ON A HIGH ALTITUDE POWERED PLATFORM (HAPP)

Prepared For

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WALLOPS FLIGHT CENTER
Wallops Island, Virginia

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CSC

COMPUTER SCIENCES CORPORATION

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By

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ABSTRACT

This report contains the results of a survey of commercially available, and unclassified military radars conducted by the Computer Sciences Corporation (CSC) for the National Aeronautics and Space Administration (NASA) Wallops Flight Center for deployment on a High Altitude Powered Platform (HAPP). This platform will be powered by a microwave link with a ground station, and will be designed to stationkeep for one year at an altitude of approximately 21 km (70,000 feet), a region of minimum wind speed and above storm effects. Some of the most promising HAPP applications in the ocean/coastal zone region include monitoring offshore oil port activity, monitoring the 200 mile fishing zone, marine traffic monitoring, and research and development in oceanography such as wave height analysis and remote sensing. A radar system is capable of meeting many of the requirements of these applications including a desirable resolution of the order of ten meters. A HAPP with a radar system has the potential of combining the desirable characteristics of both a geostationary satellite (wide area coverage, frequent observation) and an aircraft (high resolution). The system characteristics of the radar can be chosen to match a specific application. Clearly, it will be most desirable to have a radar system suitable for multipurpose and multimission operation.

A survey was conducted to find out the system characteristics of commercially available and unclassified military radars suitable for deployment on a stationary platform. A total of ten domestic and eight foreign manufacturers of the radar systems were identified. Questionnaires were sent to manufacturers requesting information concerning the system characteristics: frequency, power used, weight, volume, power radiated, antenna pattern, resolution, display capabilities, pulse repetition frequency, and sensitivity. A literature search was also made to gather the system characteristics information. Results of the survey are documented and comparisons are made among available radar systems.

The survey identified seven commercially available microwave real aperture radar systems designed for deployment on fixed-wing aircraft and helicopters. These systems have either fixed or mechanically scanning antenna, and are currently being used for varied applications including offshore oil port surveillance, and detection and monitoring of marine traffic and oil slicks. A key system parameter for these applications is the azimuth resolution. Like all real aperture systems, the azimuth resolution of these radar systems decreases as the altitude increases. If deployed on a HAPP, the resolution of these systems will be between 200 to 2000 meters.

From a HAPP altitude of 21 km if a resolution of about ten meters is desirable, then for microwave frequencies the required antenna size will be in tens of meters. The present survey could not identify a commercially available radar system which when deployed on a HAPP will provide the desirable resolution. Considering such a large antenna, a major design study needs to be undertaken which will include various trade-offs and the option of mechanical versus electrical scanning.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

Table

SECTION 1 - INTRODUCTION

The National Aeronautics and Space Administration has been studying the feasibility of deploying a High Altitude Powered Platform (HAPP). This platform will stationkeep for one year at an altitude of approximately 21 kilometers (70,000 feet) and will be powered via a microwave link with the ground station. A previous study by the Computer Sciences Corporation has identified several applications of a HAPP in the ocean/coastal zone region (Reference 1). These applications include:

- Operational Use (e.g., monitoring offshore oil port activity, and monitoring the 200 mile fishing zone)
- Navigational Use (e.g., marine traffic monitoring)
- Research and Development (e.g., wave height analysis)

A recommendation from that study is the installation of a device onboard the platform, which has a resolution of the order of ten meters and is capable of use 24 hours per day under all weather conditions. A radar could fulfill this requirement.

At the request of Wallops Flight Center, the Computer Sciences Corporation conducted a literature search, and contacted the manufacturers of the radar systems, both domestic and foreign, to gather information concerning commercially available and unclassified military radars. An attempt was made to gather relevant information concerning the system: frequency, power used, weight, volume, power radiated, antenna characteristics, resolution, pulse repetition frequency, and sensitivity. Weight, volume, and input power of the system are needed to define the platform, the booster, and the microwave link which will power the platform. The remaining system parameters are needed to define the overall performance of the system with respect to its mission. A HAPP related discussion of radar systems is given in the Appendix B.

The literature search included books, journals, and technical magazines. Although they discuss theories, principles of operation, and varied applications of a radar system, they generally do not provide all pertinent information about the system that should be considered for deployment on a HAPP. Reference 2 contains a listing of airborne military radar systems, which are of interest in this study, but complete information about most of the systems is lacking. To obtain more complete system information, manufacturers of radar systems were identified and were contacted. The results of the survey findings are documented in this report.

SECTION 2 - SURVEY RESULTS AND CONCLUSION

This section contains the system characteristics of the airborne operational radar units provided by the survey letter recipients and from the literature search (Table 2-1). Information about the SLAMMR, and RDR-1300 systems were obtained via a telephone conversation with, and a response letter from, Mr. Sam Baker of Motorola and Mr. Harry Nessell of Bendix respectively. In response to the survey letter and subsequent telephone conversation, Mr. James Wood of Raytheon Company provided the system characteristics of a radar system designated as a "Long Range Light Weight Search Radar". Since this radar is not an "off-the-shelf" operational radar system, it is listed separately in Table 2-2. This system however, does possess many of the desirable characteristics for deployment on a HAPP.

Telephone conversations with some of the letter recipients revealed that the system characteristics of many of the airborne radar systems are classified. In fact response received from General Electric had to be returned because it contained classified information; also Mr. Sam Baker of Motorola stated that the scanning mechanism and associated information about the SLAMMR system is classified. Thus a scanning SLAMMR system, although it is an operational system, may not be available for a HAPP application.

For coastal zone applications requiring 200 mile surveillance it will be desirable to have a scanning system. If a HAPP is stationed directly above the shore line then the radar system may scan 200 miles or about 87 degrees on one side of the platform or the desired area around the platform. For the latter case the system is required to have 180 degrees scanning capability with the tilt control. As stated before, the scanning SLAMMR system is classified.

If a scanning system is to be considered, then to detect moving targets, the rate of scanning is an important parameter. For a scanning rate of 15 rotations per minute, a stationary target will be detected every four seconds. This time

Table 2-1. System Characteristics of Radars (1 of 4)

Radar	SLAMMR	AN/APS-128	MAREC	APS-504(V)2
Manufacturer	Motorola, Scottsdate, Az. 85252	AIL/Cutler Hammer Long Island, N. Y. 11729	MEL, West Sussex, England RH102PZ	Litton, Ontario, Canada M9W 5A7
Platform	Airborne	Airborne	Airborne	Airborne
Antenna -				
Frequency (MHz)	9250	9375	9345	9375
Size (shape)	0.3556 x 4.8768 (flat plate)	0.4572 x 0.8382 (parabola)	0.4318 x 1.0668 (parabola)	0.3556 x 1.016 (flat plate)
Type	Fixed angle	360 and sector scan	360 and sector scan	360 and sector scan
Tilt control (deg)	0	± 15	± 10	± 15
Scan rate (rpm)	0	15, 60	30	12, 30
Beamwidth, El (deg)	7.0	5.0	4.3	7.0
Beamwidth, Az (deg)	0.5	3.0	2.5	2.5
Polarization	V	H	NA	H
Gain (dB)	37	32	34.5	33
Receiver Transmitter -				
Input Power	115 VAC, 400 Hz, 3-phase, 1200 VA; 28 VDC, 60 watts	115 VAC, 400 Hz, 3-phase, 1100 VA; 28 VDC, 14A	800 VA, 400 Hz	115 VAC, 400 Hz, 3-phase 1000 VA; 28 VDC, 10A

Table 2-1. System Characteristics of Radars (2 of 4)

Radar	SLAMMR	AN/APS-128	MAREC	APS-504(V)2
Peak Power (KW)	200	100	65	100
Noise Figure (dB)	7	8	8.5	5
Pulse Width (usec)	0.2	0.5, 2.4	0.4, 2.5	0.5, 2.4
Band Width (MHz)	Matched	Matched	2.7, 0.25	Matched
Pulse Repetition Frequency (Hz)	750	267, 400, 1200, 1600	200, 400	200, 400, 1200, 1600
Display Capability	Video, real time hard copy	Two video output, range marker	Two video output, range marker	Two video output, range marker
Weight (kg)	230	78.5	90.7	90.7
Volume (cubic meters)	0.10778	0.09804	0.36872	0.10932
Application	Search and rescue; coastal patrol; oil slick detection; ice-berg detection; ice mapping	Search and rescue; coastal patrol; navigation	Search and rescue; customs-coastguard; Pollution Detection; Fishery Protection; Off-shore Oil Rig surveillance	Search and Rescue; coastal patrol; navigation

Table 2-1. System Characteristics of Radars (3 of 4)

Radar	AN/APS-503	RDR-1300	MM/APS-705
Manufacturer	Litton Systems Ontario, Canada	Bendix Avionics Fort Lauderdale FL. 33310	SMA, Soffiano 50100 Firenze, Italy
Platform	Airborne	Airborne	Airborne
Antenna -			
Frequency (MHz)	9200-9400	9375 ±5	I-Band
Size (shape)	0.45 x 0.61 (parabola)	0.46 (circular)	1.6 meter cylindrical-paraboloid, Horn feed
Type	360 and Sector scan	Sector scan	360
Tilt control (deg)	±8	±15	±20
Scan rate (rpm)	30	12, 36	20 and 40
Beamwidth, El (deg)	5.0	4.9	10.0
Beamwidth, Az (deg)	4.0	4.9	1.5
Polarization	H		H
Gain (dB)	30	31.5	NA
Receiver Transmitter			
Input Power		115 VAC, 400 Hz, 3VA; 28VDC, 3.5A	
Peak Power (KW)	50	10.0	25.0

Table 2-1. System Characteristics of Radars (4 of 4)

Radar	AN/APS-503	RDR-1300	MM/APS-705
Noise Figure (dB)	8.0	8.0	8.5
Pulse Width (usec)	0.5	0.5, 2.35	0.05, 0.15, 0.5, 1.5
Band Width (MHz)	Matched		Matched
Pulse Repetition Frequency (Hz)	400	200, 800	1600, 1200, 650
Display Capability	Video with range marker	Video	Video
Weight (kg)	45.0	12.0	87.0
Volume (cubic meters)	NA	0.013	NA

Table 2-2. Long Range Light Weight Search Radar Characteristics (Ratheon Company, MA 01730) (1 of 2)

Transmitter	(Coherent)
Frequency (MHz)	9375
Power (ERP)	260 Watts Average 7.3 Kwatts Peak
Duty Cycle	3.5%
τ Pulse	100×10^{-6} Sec.
Chirp	200:1
PRF	330 PPS
Antenna	
Line Fed Parabolic Section Aperture	7.26 M x 1.3 M
CSC^2	Elevation Pattern
Polarization	H
Beamwidth, Az (deg)	.28
Gain (dB)	42.6
Volume (cubic meters)	0.03
Electronics	79.4 kg
Receiver	
Transmitter	
Power Supply)	22.7 kg
Modular)	
Signal Processing	
Multiplexing (to Down Link)	

Table 2-2. Long Range Light Weight Search Radar Characteristics (Ratheon Company, MA 01730) (2 of 2)

Performance	(Coherent)
Detection	
$P_d = .99$	$P_{noise} = 10^{-5}$
$S/_N = 14.0$ db	R = 366 KM
Angular Accuracy in Meters	±30 Meters Azimuth
Range Accuracy	±2 Meters Radial

Clutter Performance

At 45 Degrees = $S/_C$ = 2.4 db

At Maximum Range = $S/_C$ = 0 db

resolution together with the areal footprint of the radar beam will determine the optimum velocity of the targets for repeat detection.

The operational frequencies of all the radar systems listed are about the same. The particular frequency range is chosen because it has the smallest rain attenuation coefficient, as can be seen from Figure B-1. This will maximize the all weather application capabilities. This choice of frequency, however, imposes constraint on other system parameters, especially the antenna beam width and resolution.

If a real resolution of the order of 10 meters from a HAPP stationed at about 21 km is required, then an antenna beam width must be of the order of milliradians. As discussed in Appendix B the beam width is directly related to the size of the antenna. For a flat plate antenna like the one in the SLAMMR system, the size of the antenna should be about 60 meters. This size is significantly larger than the one currently available on the operational systems. The SLAMMR system, which has about a five meter antenna, provides the smallest beam width (0.5 degree) of all the commercially available systems listed. In its present configuration, if the SLAMMR system is deployed on a HAPP, the areal resolution will be on the order of 200 meters, which is much larger than the desired 10 meter resolution. Table 2-3 shows the azimuthal resolution for the systems listed in Table 3-1.

It is obvious from Table 2-3 that the radar systems as they are configured will not be able to meet the 10 meter resolution requirement. An improvement of over 100 fold is necessary in same cases. Further research and development will be necessary to meet the required resolution.

Table 2-3. Areal Resolution* of Radar Systems from 21 km Altitude

Radar	Resolution (m)
SLAMMR	201
AN/APS-128	1210
MAREC	1008
APS-504(V)2	1008
AN/APS-503	1613
MM/APS-705	605
RDR-1300	1977

*Resolution is computed as 1.1 beam widths

The problems associated with large antennas are many; the major ones are related to launch and retrieval, and cost of operation. The cost varies depending on the type of platform. The situation is less severe for airships than for air planes. Most present airframes are of very limited payload capacity (less than 50 kg). Heavy payload will require the airplane to circle on a larger diameter and steeper angle of bank. The cost of the ground transmitting array will go up because it needs a lot of steerability, and the annual electricity cost will also become a large part of the total cost. Except for SLAMMR, all other systems are of similar weight.

Other radar performance characteristics which were not considered in this survey are the maintenance schedule, durability and environmental factors. The components of the radar system, particularly the mechanical components such as the antenna pedestal may require a maintenance schedule. This schedule should be considered in assessing the duration of deployment of the system on a HAPP. The life time of the electronic components should also be taken into account if continuous operation and long (e.g., one year) deployment is to be considered. Recent deployment of a synthetic aperature radar on the SEASAT-A satellite, scheduled for prolonged operation, indicates that the state-of-art can allow long life time of the electronic components. Environmental factors such as the temperature of the platform should also be considered for reliable operation of the system.

APPENDIX A - SURVEY LETTER AND RECIPIENTS

COMPUTER SCIENCES CORPORATION
SYSTEM SCIENCES DIVISION (301) 589-1545
8728 COLESVILLE ROAD · SILVER SPRING, MARYLAND 20910

The Computer Sciences Corporation (CSC) is doing a survey of commercially available and unclassified military airborne radar units, both domestic and foreign, for the Wallops Flight Center/National Aeronautics and Space Administration (WFC/NASA). The main goal of this survey is to identify suitable radar units for deployment on a High Altitude Powered Platform. This platform will be powered by a microwave link with the ground station, and is designed to station keep at an altitude of approximately 21 km, a region of minimum wind speed and above storms. Possible applications of this platform include ocean/coastal zone surveillance for marine traffic control, policing 200-mile fishing zone, and offshore oil port activity. Towards this end, CSC is soliciting information regarding the system characteristics (frequency, power used, weight, volume, power radiated, antenna characteristics, resolution, display capabilities, pulse repetition frequency, and sensitivity) of portable radar units manufactured by your company. Of special interest are radar units that are capable of use for up to twenty-four hours per day with ground resolution on the order of ten meters from an altitude of about 21 km. Since the survey results are to be presented to NASA by April 1979, an early response will be appreciated.

Thank you for your cooperation.

Sincerely,

Dr. B. J. Choudhury
Sr. Member of Technical Staff
Geosciences Systems Department (313)

BJC:gw

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APPENDIX B - INTRODUCTORY CONCEPTS IN RADAR SYSTEM EVALUATION

This section outlines fundamental ideas useful for practical evaluation of a radar system (References 3 and 4). Radar as a system for transmitting and receiving electromagnetic radiation is simply a means to an end; primary consideration is centered on the detection and ranging of desirable objects, or targets.

The ability of a radar system to detect a target, i.e., establishing as conclusively as possible the presence of a target from a measurement or a series of measurements by the receiver of the system, is the most important element in the evaluation of any system. Due to ever-present noise in the system, which at one instant interferes destructively with the received signal and at another instant constructively, the analysis of the received signal for establishing a target is intimately connected with statistical decision theory. The effect of noise on the system performance is twofold: the noise may conceal or produce a false image of a target, and it may limit the accuracy of the target parameter estimation (discussed below). Statistical decision theory provides the mathemathical framework for calculating the signal-to-noise ratio which will be required for establishing the presence of a target with a given probability, and for minimizing error in target parameter estimation. Since for a given value of the signal-to-noise ratio the accuracy of the target parameters depends upon the method of analyzing the radar signal, signal processing should be considered as an important part of radar system design and analysis.

The central issue is the ability of the system to recognize the presence (or absence) of a target. If this ability is satisfactory, then the system should be further evaluated on the basis of providing information about the number of targets, and the target itself.

B.1 RESOLUTION

Resolution in a radar system is defined as the ability to distinguish between closely spaced targets. In particular, range resolution depends upon the pulse width of the system. When a radar pulse of finite duration is transmitted, the echo will come back from both the leading and the trailing edges of the pulse. Range is measured by translating the time delay between the transmitted and received signals into distance travelled by the radiation. Two targets within the same antenna beam width but at different ranges will reflect energy at different times. As the targets get closer, the time difference between the returned energy will decrease. Thus for targets to be resolved the separation between them should be at least a pulse width, i.e.

$$\delta R = \frac{1}{2} C \delta \tau$$

where c is the velocity of light and $\delta \tau$ is the pulse width. From this equation it can be seen that ten meters range resolution will require a pulse width of less than 0.07 microsecond. This pulse width is within the capability of modern radar technology. Pulse compression techniques can also provide this resolution.

Another important consideration is target angle or azimuth resolution. As the radar beam sweeps past a target, the reflected energy (the signal amplitude) will build up to a maximum when the center of the beam falls directly on the target. If two targets are widely separated in angle i.e., angular separation larger than the beam width (the angle across which the radar beam reached half of its maximum power) then corresponding to each target there will be an amplitude maximum of the return pulse. As the separation decreases, the two pulse maxima will start overlapping and finally will appear as a single pulse. The narrower the radar beam, the closer the targets can come and still be distinguishable. If two targets return an equal amount of energy then they can be distinguished if they are separated by at least an antenna beam width. The Rayleigh criteria of resolution requires that the targets be separated by 1.12 beamwidths. For a uniformly illuminated antenna, the beamwidth is related to the antenna size and the wavelength as follows.

For a rectangular antenna:

$$\text{Azimuth beamwidth } \theta_a = 0.88 \frac{\lambda}{W} \text{ (radians)}$$

$$\text{Elevation beamwidth } \theta_e = 0.88 \frac{\lambda}{h} \text{ (radians)}$$

where W and h are respectively the width and the height of the antenna measured normal to the beam.

For circular antenna:

$$\text{Beamwidth } \theta = 1.02 \frac{\lambda}{D} \text{ (radians)}$$

where D is the diameter, and λ is the wavelength of the radiation. For resolution on the order of ten meters from an altitude of approximately 20 km, the beam width should be smaller than 0.5×10^{-3} radians (or 0.028 degree). This then requires that the size of the antenna should be about 2000 times the size of the wavelength. For an X-band (wavelength 3 centimeters) system the antenna size should be about 60 meters and for a K_a -band (0.86 centimeter) system the antenna size should be about 17 meters.

Figure B-1 shows the relationship between wavelength and antenna size for a desired resolution of 10 meters at an altitude of 20 km. It is obvious from Figure B-1 that it is advantageous to operate the radar at shorter wavelengths to reduce the required antenna size. However, there are other considerations which have to be taken into account.

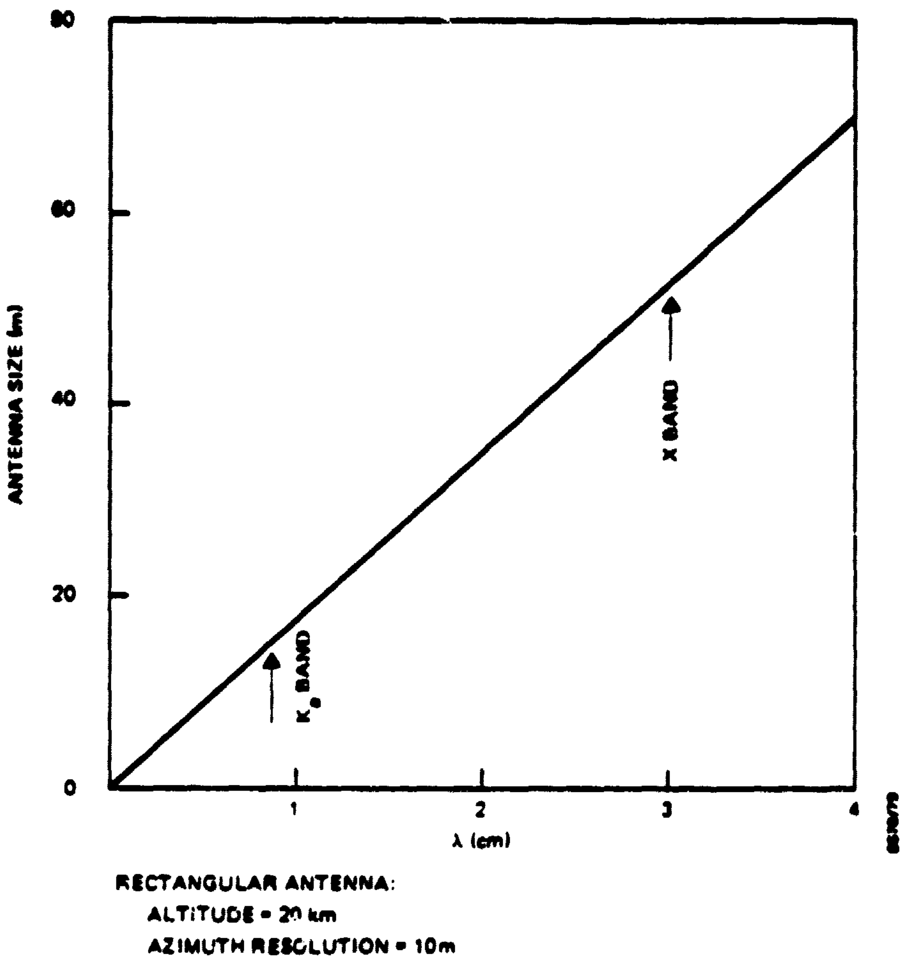

Figure B-1. Dependence of Antenna Size on the Operating Wavelength

There are several incentives for reducing the size of the antenna for HAPP applications. Antennas are the key component which determines the weight of a radar system (about 8 kg/m^2, see Table 2-2). Not only is the weight of the system a constraint for deployment, but on a HAPP an antenna of large dimension (50 meters) together with its weight can have an unstabilizing influence on the platform. A large antenna will require packaging and unfolding, and it must survive shock, acceleration, and vibration during launch. After unfolding it must have long life with a high degree of reliability. The design must permit laboratory calibration and testing. The difficulty of providing quality assurance increases with the antenna size. Thus weight and reliability are prime factors for choosing an antenna of smaller size (several meters).

Another underlying consideration for a smaller antenna is the annual operating costs of providing microwave power to keep the platform in place. The current plan is to use the 2.45 GHz for transmitting power to HAPP (Reference 14). Heavier payload will require higher power density of transmission and thus higher cost.

The factors which must be considered for choosing the wavelength are the atmospheric attenuation and clutter. The effect of these is to degrade the target detection probability. The atmospheric attenuation is directly proportional to the path length of radiation. Hence the signal attenuation will increase with the slant range of the target. To counterbalance the attenuation, the transmitting power must be increased. The effect of atmospheric backscattering can be considered as clutter or noise as far as detection of targets is concerned. Theoretical and experimental backscatter information may be used to suppress the noise so as to detect and analyze the desired signal.

If all weather operation of HAPP is desirable then attenuation and clutter due to rain and snow must be considered. For ocean/coastal zone applications, the sea-surface return will be clutter. At this point, the choice of polarization of radiation becomes important because clutter is polarization dependent.

The desirable angular resolution and detection at maximum range with constraints on the antenna size and available power can be achieved if target detection degradation due to attenuation and clutter can be restored by proper choice of wavelength and polarization. Note that although clutter suppression is generally performed by a software based hardware signal processing system which does not directly require a trade-off with vital system parameters (weight and input power), this noise can severely hamper the target detection ability of the system. The issue of trade-off is basically detection capability vs. input power, and resolution vs. weight. The key parameters in this issue are the wavelength and polarization of the radiation. Therefore it is important to have information about the wavelength and polarization dependence of attenuation and clutter from rain, snow, and sea surface return. For HAPP applications in the ocean/coastal zone regions of the southern United States (e.g. monitoring of Louisiana offshore oil port activity, monitoring of the 200 mile fishing zone, detection of oil spills and oceanographic research) one may not consider attenuation and cluttering by snow. For many oceanographic research (e.g., wave height analysis) the sea surface return is not clutter but the desired signal

Signal attenuation and clutter from rain, snow, and sea-surface return for different wavelength and polarization are studied in References 5, 6, 7, 8 and 9. In Figure B-2 rain induced attenuation is shown for 32, 8.6, and 3.2 mm. wavelength radiation (Reference 6). The maximum rain rate for which the attenuation coefficient is shown in Figure B.2 (20 mm/hr) corresponds to torrential rain, not uncommon in the south-eastern coastal regions of the United States. The rain forming cloud is generally about 8 kilometers high.

To illustrate the implication of the attenuations coefficients shown in Figure B.2 let a HAPP be stationed directly above the shore line. For targets at 200 miles offshore, which is the maximum desirable range for observations, the signal path length through rain is about 120 kilometers. Thus the total path length for

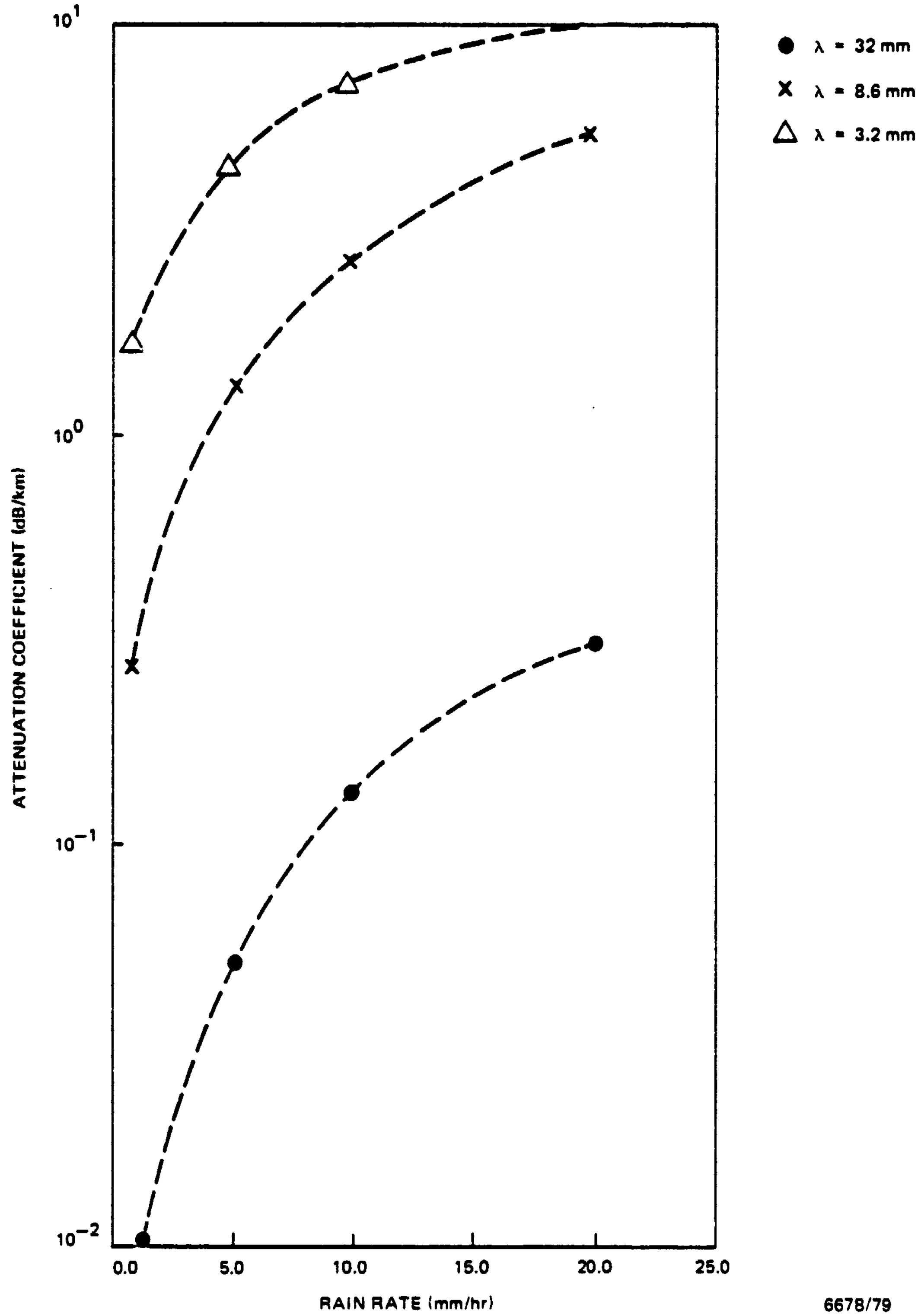

Figure B-2. Rain Attenuation Coefficients for Microwave Radiation the transmitted and the received signals through rain will be about 240 kilometers. For 20 mm/hr rain rate, the total attenuation of the transmitted and received signals will be 72, 1253 and 2611 db at 32, 8.6 and 3.2 mm wavelength radiations. These attenuations are such that a target may not be detected even in the absence of any clutter effect. It can be seen from Figure B.2 that the 32 mm wavelength will be the best candidate for an operational all weather satellite. To ascertain the trade-off between the input power and the target detection at different ranges, one needs to analyze the meteorological records to determine the fractional time for different rain rates.

Mechanical scanning by heavy and large antennas entails severe structural problems. Moreover, the possible rate of scanning is limited. These limitations can be overcome by a phased array antenna where the beam steering is accomplished electronically with no need for mechanical motion. Also a phased array antenna can satisfy the need for multifunction operation (such as simultaneous surveillance, and tracking), coupled with high power, high data rates, and ability to withstand adverse environmental conditions.

A phased array antenna is an ordered array of radiating elements. Beam steering is performed by applying phase shift to the antenna elements. Unlike a single element antenna (e.g. a flat plate or a parabolic disk) the performance analysis (e.g. beam width, antenna gain) of a phased array antenna is significantly more complicated. The radiation pattern of a phased array antenna depends on the array geometry and the radiation pattern of each element. Due to mutual coupling, the radiation pattern of the various elements depends upon their relative positions. The radiation pattern of elements within is different from the elements at the edges of the antenna. Unlike a single element antenna, the antenna pattern and the beamwidth of a phased array antenna changes as the beam is scanned away from the array normal. Methods of optimization and antenna performance are discussed in References 10 and 11. A microstrip phased array antenna may be advantageous for HAPP applications because this antenna can be produced on a thin (typically 1/64" to 1/8") printed circuit board and attached to the outer surface of the platform, and is claimed to have low cost and high reliability (Reference 12).

The phased array antenna technology, though promising, still requires much research and development effort. A microcomputer will be needed to control the phase shift to antenna elements to optimize antenna gain while the beam is being steered. This technology is generally not utilized in the commercially available radar system.

B.2 TARGET PARAMETERS

Important information about the target are values of parameters describing the target, include range, azimuth, elevation, range rate, azimuth rate, elevation rate, size, and shape.

Target range produces a delay of the received signal with respect to the transmitted signal. In the monostatic case, i.e., receiving antenna at the same location as the transmitting antenna, unambiguous identification of the received signal with respect to a transmitted pulse requires that the signal must be received within the time corresponding to the inverse of the pulse repetition frequency. Thus, the unambiguous range of a target, R, is related to the pulse repetition frequency, ν_p, by the equation

$$R = \frac{1}{2} c (\nu_p)^{-1}$$

where c is the velocity of light. If the transmitted signal and the received signal were exact replicas of each other, then the accuracy of the range measurement will depend solely upon the accuracy of the delay measurement. In practice this accuracy is limited because of noise and the pulse width of the transmitted and received signals. The question of resolution of closely spaced targets, is directly related to the pulse width. As stated previously, reliable information extraction in the presence of noise is a part of signal processing.

One of the problems in pulse radar systems is that if one wants to detect targets at considerable distance then to get a good energy return (for improving the detection probability) either a wide enough pulse or a fast enough pulse repetition rate is to be used so as to get sufficient energy on the target. Too wide a pulse interferes with range determination capability (see criteria for range resolution), and too many pulses per second interferes with correlating the echo with the target (see criteria for unambiguous range). The solution to this dilemma is through pulse compression. The idea is to stretch a short pulse on transmission so that it has higher energy content and then compress the received signal. If a 0.1 microsecond pulse is stretched to 20 microsecond then the energy content may be increased by a factor of 200.

Naturally, the pulse compression technique can be used to improve range precision without sacrificing the detection capability for targets at large distances (Reference 13). In a system design the pulse repetition rate is decided first to provide unambiguous ranging for the desirable space. The pulse width is set to provide required range resolution. The peak transmitting power is then set to achieve the average power level needed for detection at maximum range. If the required peak power level is not attainable then an alternate design is used. The pulse width is set to permit recovery of the receiver for the minimum search range, and the pulse compression technique is used to obtain the required range resolution. For a HAPP application since the available power is a constraint, the latter design will be preferable.

A change in target azimuth and elevation cause variations in the received signal amplitude because of the angular dependence of radar antenna gain. As the radar beam moves past the target, the amplitude of the signal will show variations. Correlation of the antenna gain pattern with the amplitude variation provides estimates of target angle location. Thus, unlike range, the angle information is not obtained via an equation but through pattern matching.

Target range rate is estimated using the Doppler effect. If the transmitted signal is a sine wave of frequency f_t, the received signal will be a sine wave of frequency f_r given by

$$f_r = f_t - \frac{2\dot{R}}{\lambda_t}$$

where $\dot{R}$ is the target range rate, λ_t is the transmitter wavelength. Thus for a target approaching the radar at velocity V, the frequency of the received signal will be increased by an amount $2V/\lambda_t$.

Target azimuth and elevation rates are estimated by making a series of azimuth and elevation measurements over a period of time and then finding the slope of the measured values.

Target shape and size information are contained in the amplitude of the received signal. However, it is rather difficult to extract this information because of the many interactive variables, and most radar analysis assumes that the target is only a point.

REFERENCES

1. Computer Sciences Corporation, Technical Memorandum CSC/TM-78/6331, A Survey of Potential Users of the High Altitude Power Platform (HAPP) In the Ocean/Coastal Zone Community, D. Escoe and P. Rigterink, 1978

2. R. T. Pretty (editor), "Jane's Weapon Systems", New York, Franklin Watts Inc, 1978

3. R. S. Berkowitz (editor), "Modern Radar", New York, John Wiley and Sons, Inc., 1965

4. D. K. Barton, "Radars", Vol. 4, Dedham, Massachusetts, Artech House, Inc., 1975

5. L. J. Battan, "Radar Observation of the Atmosphere", Chicago, University of Chicago Press, 1973

6. F. B. Dyer, N. C. Currie and M. S. Applegate, Radar Backscatter From Land, Sea, Rain, and Snow at Millimeter Wavelengths, International Conference Radar-77, pp. 559-563, 1977

7. J. Goldhirsh and I. Katz, Useful Experimental Results for Earth-Satellite Rain Attenuation Modeling, IEEE Transactions Antenna and Propagation, vol. AP-27, pp. 413-413 (1979)

8. L. R. Flumerfelt, Summary of Results of a Recent Sea Clutter Measurement Program, IEEE Transactions Antenna and Propagation, vol. AP-27, pp. 416-417 (1979)

9. D. B. Hodge, "The Effect of Precipitation on Radar Target Identification and Imaging", pp. 379-398, in Atmospheric Effects on Radar Target Identification and Imaging, H. E. G. Jeske (editor) Boston, D. Reidel Publishing Company, 1976

10. D. K. Cheng, "Optimization Techniques for Antenna Arrays", Proceedings of IEEE, vol. 59, pp. 1664-1674 (1971)

11. W. H. VonAulock, "Properties of Phased Arrays", Proceedings of IRE, vol. 48, pp. 1715-1727 (1960)

12. R. E. Munson, "Microstrip Antenna Technology at Ball Aerospace Systems, Boulder, Colorado", IEEE Antenna and Propagation Society Newsletter, vol. 21, no. 3, pp. 5-6 (1979)

13. D. K. Barton, Radar System Analysis, New Jersey, Prentice-Hall, Inc., 1964

14. J. W. Sinko, "High Altitude Powered Platform Cost and Feasibility Study", SRI Project 5655-502, Stanford Research Institute (1977)

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16. Abstract
This report contains the results of a survey of commercially available and unclassified military radars for deployment on a High Altitude Powered Platform (HAPP). It was conducted by Computer Sciences Corporation for the National Aeronautics and Space Administration, Wallops Flight Center. The design goals of a HAPP include station keeping at a working altitude of 21 km (70,000 ft) and a lifetime of one year. Promising applications of a HAPP include monitoring off-shore oil activity, monitoring the 200 mile fishing zone, marine traffic monitoring as well as research and development in oceanography where continuous monitoring is needed. A radar system has many of the characteristics necessary to accomplish these monitoring tasks. A survey was conducted to investigate the system characteristics of available radars suitable for deployment on a high, stationary platform. Ten domestic and eight foreign manufacturers of radar systems were identified. Questionnaires were sent to these companies requesting information concerning their radars. A literature search was also made. Results of the survey are documented; seven commercially available real aperture microwave radar systems were identified that have been used on fixed-wing aircraft and helicopters. At the HAPP altitude these systems have a resolution of 200 to 2000 meters determined principally by the size of the antenna. A desirable resolution for this radar is on the order of 10 meters implying an antenna tens of meters in diameter; this indicates the need for a major study to investigate the trade-offs available and optimum antenna design for a HAPP radar.

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