INTRODUCTION

The Intelligence Problem

A long-standing requirement exists to collect electronic intelligence from the interior and infrequently covered maritime regions of Russia. By use of the proposed satellite the "S" Band radar disposition in the Soviet Union would be scanned approximately 14 times per day. By interrogating the satellite only on a planned and programmed selection of passes carefully selected data giving the geographical disposition of the Soviet radars in this important band can be determined. The data would be collected by the existing U. S. and friendly ELINT stations and processed in the usual ELINT channels. To maintain security in the operation, the satellite would transmit the ELINT data being collected only after interrogation by one of the ELINT stations. The effect would be one of extending the horizon of each ELINT site at least twice per day to a range of 2000 miles for a period of approximately 15 minutes.

Operation of the Satellite

The proposed satellite would be launched in a 70° orbit at an altitude of between 400 and 600 miles. The orbit would be established by tracking a small 20 milliwatt transmitter at 108 Mc by the existing Minitrack stations. After a few passes the Vanguard system could produce an Ephemeris for the subsequent passes for all the ELINT intercept sites for the life of the satellite. By using 108 Mc to establish the orbit a cover plan could be evolved which would be effective.

The satellite would carry two transmission systems, one at 108 Mc for tracking which would be powered by solar cells and operate when powered by the sun (approximately 70% of the time) and one at 86 Mc which would transmit the intercept data only upon interrogation. A simple crystal-video system would be used to intercept the Soviet "S" Band radar transmissions and the output of this receiver would modulate the output of the 86 Mc transmitter with the signal characteristics of the incoming "S" Band signal. A life of approximately 12 months can be obtained from a 20 inch satellite weighing approximately 35 pounds. This unit should provide adequate fixes on the majority of the higher powered "S" Band radar systems in use ashore and afloat.

Background

The Countermeasures Branch of the Laboratory has a lengthy background of experience in the electronic intelligence field and this proposed program consists of a reduction to practice of certain research techniques presently under investigation and others now available. The data gathered would materially assist the continuing research program of the Laboratory by providing experience in dealing with high-density signal analysis and identification. This program is part of a broader project to develop electronic intelligence instrumentation for all supersonic vehicles of the future under the Bureau of Aeronautics sponsorship.

Satellite Performance Characteristics

As shown in Fig. 1, with the satellite in a typical orbit of 500 mile altitude, it will be illuminated by, and will intercept, the main beams of two typical Soviet radars, Gage and Token. The time duration of the intercept of the Gage signal will be about 2 1/2 minutes and about one minute for each of two lower major beams of the Token radar, during the period when the satellite is approaching the radar site. Due to the fact that the radar antenna patterns are not highly directive upward, the satellite will lose contact when it is above the major beam of the radar and will intercept the radar again during the period when the range between the satellite and the radar is increasing. Figure 1 illustrates the particular case when the satellite is to pass directly over the radar site.

In Fig. 2, the map is a northern hemisphere polar stereographic projection with standard parallel at 40 degrees north latitude. The Soviet Territory is the central land mass with the pink color. The tracks for a 70-degree orbiting satellite are shown numbered in sequence with number 1 being the first pass following the launching from Cape Canaveral, Florida. The arrow heads on each orbit track indicate the direction of travel of the satellite. Six light-blue circles are shown which represent the data-link intercept ranges from the present ELINT sites located in [redacted] (b)(1) (b)(3) These circles are also indicative of the area about these sites in which the satellites can be interrogated. At a satellite altitude of 500 miles the range would represent a circle whose radius is 1850 statute miles.

Figure 3 shows the data-link ground range as a function of satellite altitude. This gives the distance from a point on the earth directly below the satellite, at which the transmitted data can be received by a ground station. The curve shows that the maximum range occurs at an altitude of 500 miles. At lower altitudes the range is limited to the line-of-sight distance, while at greater altitudes the limitation in range is due to the free-space attenuation of the signal.

Referring again to Fig. 2, an orange circle is shown at the right of the center at the bottom of the figure. This represents the intercept range of the satellite's "S" Band receiver. As shown in the figure, the satellite is positioned (center of orange circle) at the extreme range of the ELINT intercept [redacted] At the moment it is interrogated it would be intercepting the radars in the perimeter defenses of the China coast. As explained above, the intercept area would consist of a circular band at the periphery of the orange circle (outside the white hatched area). This would constitute a band extending inward from the periphery of the circle approximately 600 miles. As the satellite continues northward on the track of pass number 1 in Fig. 2 the sector being swept by the satellite will move northward. When it passes a point directly opposite the intercept station to the west it will begin its backward looking sweep of the China coast.

At some point just before it passes out of range of the [redacted] on orbit number 1 it will come within the range of the [redacted] and this station will then begin to collect the intercept data as the satellite continues northward in its flight. A similar path can be traced for each pass (b)(1) (b)(3) showing the satellite's relation to each intercept station and the general coverage afforded by each pass. Each day the track of the passes will shift slightly and in the course of a week's time approximately 100 passes over the Soviet Union will have been made. By correlating the data obtained in the various passes over a certain area, the accuracy with which a certain radar or group of radars can be "fixed" will improve. At the end of two weeks an accurate picture of the "S" Band radar defenses of the Soviet Union can be drawn.

Since the basic intercept system used will be a crystal-video system with an overall sensitivity of -47 DBM, the side lobe power of the radar will not be strong enough to reach the satellite. This is shown graphically in Fig. 4. For example, a radar of the Token class with an effective peak power of 0.4 megawatt and an antenna gain of 40 db (G_T) could be intercepted by the satellite receiver at a range of 3000 miles. Now if it is assumed that the side lobes of the radar are down 20 db the curve shows that the range against these lower powered components of the antenna pattern is only 300 miles. The satellite will be placed in orbit between 400 and 600 miles above the earth, and none of the side lobes of the Token will be detectable by the satellite.

Technical Details of the Satellite

The basic electronics system in the satellite is shown in Fig. 5 as a block diagram. The description of the essential components of the system will be based on this diagram.

General Construction

The electronic circuitry of this intercept system will be of the building block type which will allow the maximum use of standardized components in various types of satellites. In general, printed circuit boards will be employed to provide uniformity as well as to reduce the cost and weight. An effort will be made to keep the overall weight to an absolute minimum without sacrificing reliability. Circuits will be potted into circular wafers which are 8 1/2 inches in diameter, with components displaced so as to maintain dynamic balance about the longitudinal axis of the launching vehicle.

Intercept System

The intercept system will consist of multiple antenna elements spaced around the satellite such that adequate coverage will be had for all orientations. This is necessary due to the probability the satellite will be in continuous rotary motion.

The intercepted signals will be confined to a predetermined frequency band by the use of a band pass filter located between the combined antenna input to the system and the detector. By using very broad frequency coverage antennas, the intercept operating band could be predetermined anywhere in the range 2500 - 10,000 Mcs. For the first unit, the band covered would be 2600 to 3250 Mc. The pulses of r-f energy intercepted by the antennas are accepted by the band-pass filter, detected by the crystal detector, then amplified and stretched prior to being rebroadcast by the data-link transmitter.

Data Link Transmitter System

The video amplifier is followed by the Modulator. Besides driving the Data Link Transmitter, the Modulator alters the pulse shape of the signals putting more energy into the audio frequency spectrum, i.e., the pulses are stretched in time duration.

The Data Link Transmitter is a crystal-controlled oscillator followed by two transistors operating in parallel which consume very little power during the time of no modulation. During the signal pulses, the transmitter is capable of putting out approximately 500 milliwatts peak power, the efficiency of this transmitter is estimated to be about 55%. During the periods of no modulation the oscillator power consumption drops to 25% of the maximum or modulated power, thus effecting another saving of battery life.

Command System

The satellite will contain a command receiver which, when interrogated, will actuate an interval timer, apply power to the Intercept System, and the Data Link Transmitter, and turn off the Command Receiver, for the period of the timer (about 30 minutes). The command signal is received on the turnstile antenna system and is fed to the command receiver by means of a hybrid phasing network. The local oscillator of the command receiver is a self-contained crystal-controlled unit so the frequency of this command signal may be changed from one satellite to another. For the first satellite, the command frequency will be in the vicinity of 75 Mc.

Batteries

The electronics instrumentation, with the exception of the tracking transmitter, will be battery operated. The intercept receiver, data transmitter and command receiver will each use the required number of mercury cells, while the tracking transmitter will operate from solar cells.

The command receiver will operate continuously while the intercept receiver and associated data transmitter are turned on for 30 minutes during selected passes. Only 25 percent of the total number of passes will be interrogated and minimum battery life of 12 months is expected.

Weight and Size

The total weight of the satellite, including the spherical shell, internal structure, antennas, instrumentation and batteries will be 35 pounds. The diameter, exclusive of solar cells and antennas will be 20 inches. The instrumentation and batteries will be contained in an internal cylindrical compartment 8.5 inches in diameter and approximately 9.5 inches long.

Interrogation Transmitter

In order to interrogate the command receiver in the satellite from the ground, it is necessary to illuminate the satellite with an interrogation signal, modulated with an audio tone previously chosen in the 1500 to 3000 cycle range. This signal must persist for at least one tenth of a second. Since the sensitivity of the command receiver is quite high, being in excess of -100 dbm, line-of-sight interrogation ranges against a satellite at altitudes from 200 to 1500 miles will be possible using a 200-watt transmitter radiating from a relatively low gain antenna.

An examination of Figure 2 will show that such a transmitter located at [redacted], could interrogate all orbits within line-of-sight which are those numbered #4 through #10. These passes provide overhead coverage of the entire Soviet territory except that small portion which lies (in the figure) above the orbit #4 in the Kamchatka-Bering Straits vicinity.

Ground Based Receiving System

The present ELINT facilities which are to be used as intercept sites for receiving the signals radiated from the satellite are at present equipped with excellent receiving equipment in a frequency range including 86 Mc. While it is possible to utilize these receiving and recording facilities, it would be more desirable to fit and equip separate standardized small "ESV Huts" for each site. These huts are transportable shelters large enough to hold the entire ground instrumentation and two operators. The huts would have a rotatable antenna mast, complete with steering and braking devices. A Corner-Reflector type antenna on this mast would be adequate for reception of the satellite signal and would provide a half power beam width of about 60 degrees.

A Time Standard would be necessary to put timing information on the dual track 15 inches per second tape recordings with the satellite signal.

CONCLUSIONS

The proposed Electronics Intelligence Satellite is based on known techniques and is within the state of the art today. This program is a part of the initial effort necessary to explore the operational aspects of the broader research program, particularly those related to data handling. The satellite will provide a vast amount of intelligence not now available from any other programs. This satellite could be launched by any number of existing combinations of rocketry. The use of the 108 Mc Vanguard frequency to establish the tracking Ephemeris required to direct the ground data link operations, provides an excellent cover for the classified portions of the experiment. Since the classified Electronic Intelligence telemetering part of the Satellite's operation will be on an undisclosed frequency which is actuated only when interrogated, it will be difficult for some casual observer to detect. When the satellite begins to return to earth it will disintegrate due to the heat generated in passing through the earth's atmosphere thus leaving no tell-tale evidence which might be used later to embarrass us about the nature of the operation conducted.

FUTURE PROGRAM

The proposed "S" Band Satellite has certain common components which are adaptable to many other frequency ranges by simply changing the input components to the crystal video system. It is proposed that a second Satellite utilizing "X" Band would be launched to survey the Soviet Union for "X" Band emissions following the successful launching of the first Satellite.

To provide data on the correlated activity on two frequency bands simultaneously it is proposed to build a somewhat larger two-band Satellite which would cover both "S" and "X" bands first. Following this would be an "L" and "X" Band Unit and later an "S" and "L" and still later an "S" and "C" Band Unit. While these two-band units would be a part of a future program, their planning should also begin on the approval of this project. All of these satellite programs would utilize common components insofar as possible.