OXC-5723
Copy 1 of 3

27 September 1963

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[redacted]

MEMORANDUM FOR: Deputy for Technology, OSA

SUBJECT : Westinghouse Progress Report - 1 July 1963 - 30 July 1963

Attached for your information and file are two (2) copies of Subject report.

[redacted] 25X1

Chief, Contracts Division, OSA

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Box [illegible], Baltimore [illegible], Md. 21203
Telephone [illegible]

SECRET

September 11, 1963

Advanced Plans & Programs Division (ASZ-5)
Deputy for Systems Management
Hq. Aeronautical Systems Division
Wright-Patterson Air Force Base, Ohio

A18848T

SUBJECT: Contract AF 33(600)40280; Submission of Progress Report for July 1963; Westinghouse Reference DYD-45196.

Enclosure (1): Three (3) copies of Progress Report for the period of July 1, 1963 to July 30, 1963.

Gentlemen:

In accordance with the subject contract, we are enclosing the monthly Progress Report for July.

Very truly yours,

WESTINGHOUSE ELECTRIC CORPORATION

[redacted] 25X1
Marketing Specialist
Marketing Department

RWE:sk
Encl.

cc: [redacted] (with one copy of Enclosure) 25X1

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COPY 2 OF 3

PROGRESS REPORT

Period of July 1 to July 30, 1963

Contract No. AF33(600)40280

TABLE OF CONTENTS

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A FLIGHT TEST PROGRAM

GENERAL

Specific targets recorded during the three flights (70 to 72) made this month are city parks, railroad yards, portions of Fort Meade, Maryland, storage sheds and buildings at the Army Ordnance Depot in Baltimore, and structures of the Bethlehem Steel Mills at Sparrows Point, Maryland and of Fairless Steel Mills near Trenton, N. J. Other general targets resolved are highways, housing groups, railroads, and harbor facilities.

Azimuth resolution is improved over recent flights due to operating the system with an unusually high offset frequency, 275 to 330 cps. Many dots with 5 mil (20 - 25 feet) azimuth dimension are registered and many instances of only 3 mil (12-15 feet) dot separation are recorded. The range of equivalent ground distance depends on the scale factor used when preparing the correlated film.

The aircraft doppler navigation system which supplies drift angle information to the pilot and ground speed information to the automatic film speed control failed on all three flights. However, by setting the system VFO for "leakage zero beat" and flying the aircraft on a heading which maintained the antenna pod at zero degrees, the pilot was able to determine his course for a zero drift flight. The pilot then maintained a true airspeed required to achieve a ground speed of 830 knots. A constant 830 knot signal to the film speed control established a recorder film speed of 1.224 inches per second.

PRIMARY FILM

The focus of the projection of the CRT trace onto the film was improved by adjusting the CRT in its mount. However, the first 3/4 inches of each range sector is slightly defocused. This may be due to poor dynamic focusing, further misalignment of the CRT or a combination of both of these items.

Striping due to vibration is very bad. This striping of 200 cps has higher amplitude in the near range sector than the far range. The far range sector has an additional frequency component too high to be measured with handviewers which is probably the 480 cycle measured on the optical correlator. Frequency components up to 300 cps can be detected during function generator tests by using a 12X magnifier. Higher frequencies than this may be recorded, but are masked by the striping.

The primary video (oatmeal) recording is very high in frequency and low in amplitude because of the higher offset frequency used on flights 70 to 72. The doppler frequency tracker was set to track between 330 and 275 cps on the last three flights while previous flights utilized an offset frequency of 225 to 250 cps. Despite these higher offset frequencies, many zero and near zero holograms were produced, caused by targets which are illuminated by the antenna skirts and side lobes.

As an aircraft approaches a point target the doppler shift in frequency due to the target is $F_d = \frac{2V}{\lambda} \sin\theta$, where V is aircraft velocity, λ is radiated wavelength, and θ is the angle in azimuth of the target from a line normal to the aircraft flight path.

Figure 1 represents the azimuth radiation pattern of the system antenna, and the following is a tabulation of approximate doppler frequencies at points along the antenna pattern.

db	Doppler Frequency Leading	Doppler Frequency Trailing
0	0	0
1	74	120
3	134	220
6	195	316
10	243	414
10.5	245	420

With an operating offset frequency of 250 cps above the reference frequency, any target giving return below 10 db would produce "oatmeal" or holograms starting low and increasing in frequency. However, very large targets exceeding this 10 db point would produce doppler frequencies beyond the offset thus producing holograms going from high to zero to high. The higher the offset frequency, the fewer zero holograms and the higher the oatmeal frequency.

While a high offset frequency reduces holograms passing through zero, a desirable advantage, it also accounts for weak oatmeal registration on the primary film. As noted, the primary recording is one of a frequency inversion process. Targets which produce low frequency doppler (such as ground return) also produce high frequency "oatmeal". A high offset frequency produces oatmeal frequencies which approach or exceed the recorder band-pass and thus produces weak film exposure.

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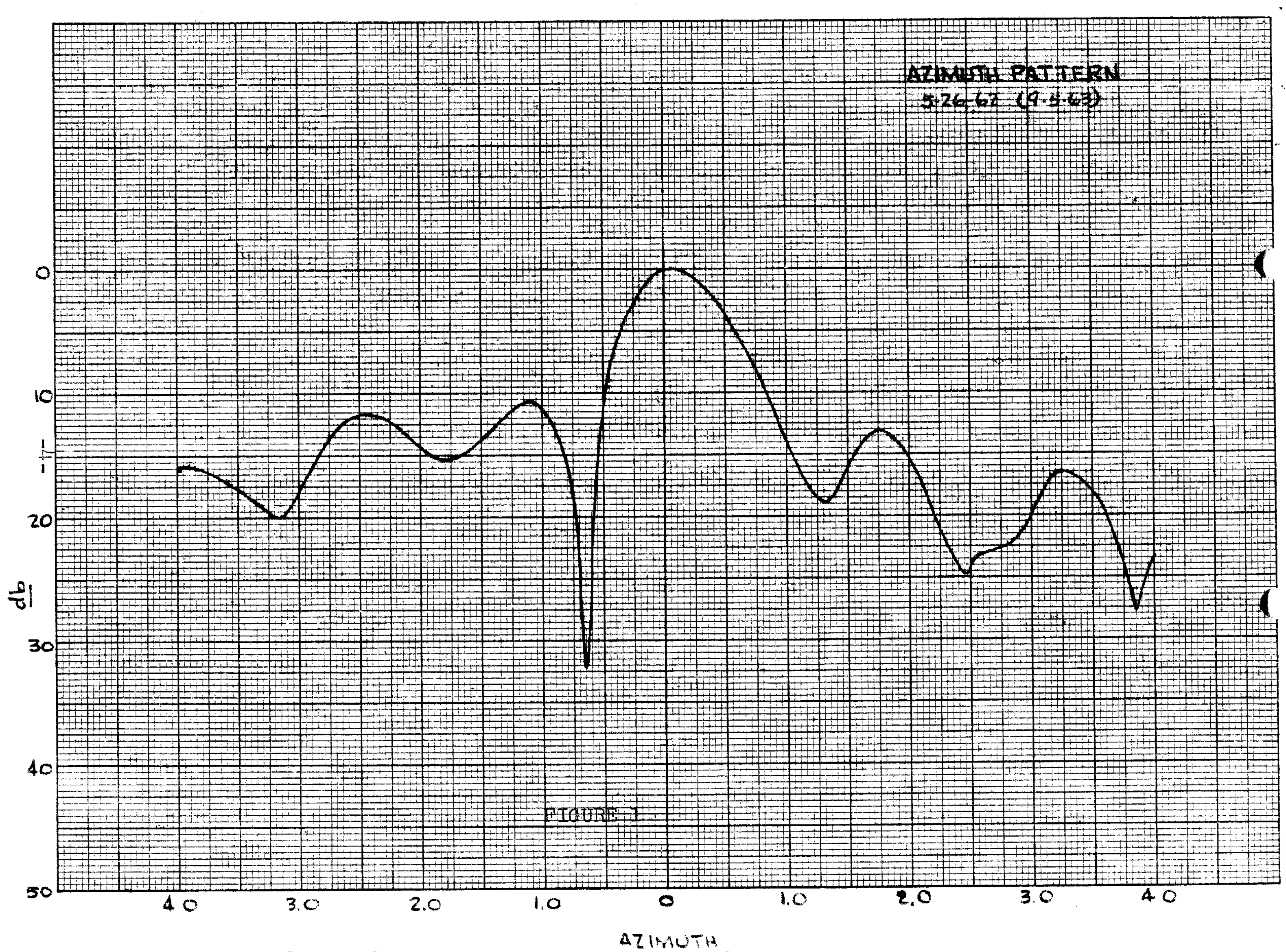


FIGURE 1

CORRELATED FILM

A radar map was produced from each of the three primary films recorded this month. In general, video is weak but strong enough to allow comparison of the aircraft flight path with maps. Unfortunately, the heavy vibration striping on the primary film is also on the correlated film and detracts from the map quality.

A time marker is needed on the correlated film to permit easier interpretation between the primary and secondary films. When the primary recordings are weak or if land-water contours are not visible, it is difficult to identify "land-marks" to establish correlation.

Many dots registered on the secondary film have range "feathers" caused by excessive pedestal amplitude in the transmitted pulse. These feathers are bright lines ahead of and behind the main dot representing a target and vary with target size. Typical target dimensions are 5-10 mil actual dot size, 10-20 mil leading feather, and 5 mil trailing feather. Holograms producing feathers are approximately twice as wide as holograms without range feathers.

No azimuth distortion or azimuth feathers were noted on S-70 and S-71 film. Typical azimuth dot sizes measured on these films are 5 to 10 mils (20 to 40 feet) and many instances of 3 mil (12 to 15 feet) separation were detected.

On S-71 film, there are several instances where dots appear to be stretched diagonally. However, close examination with a 12X magnifier reveals adjacent dots are running together due to what looks like film over-exposure. Spacings of 3-10 mils can be measured between the range feathers of these specific targets.

The majority of dots on S-72 film are slanted. However, this slanting is a function of the correlator range filter. Dots above the horizontal line produced by the junction of the correlator range filters are vertical - those below this line are slanted. Also, the area above the range line is defocused - striping as well as video.

Specific examples of azimuth feathers caused by zero holograms on S-72 film are described by the following tabulation.

Target	Azimuth Dot Width (mils)	Leading Feather Length (in.)	Hologram Frequencies Leading	Hologram Frequencies Trailing
1	15	0.135	95	220
5	20	0.435	220	220
6	18	0.175	95	280
7	5	No azimuth feather	0	180
8	7	No azimuth feather	0	200

It may be concluded from this month's data that improved azimuth resolution is realized by operating with a high offset frequency. However, this procedure produces weak background video which must be overcome by increased RF power or, better still, increased RF bandpass of the recorder.

INSTRUMENTATION

An analysis of data from this month's flights indicates there is good correlation between antenna position, VFO position, and drift angle 75% of the time, indicative of good tracking.

Instrumentation modifications are being made concurrent with APQ-93 modifications. They will provide performance and environmental data on the new transmitter, and will double the "quick look" capabilities of the magnetic tape instrumentation. An additional 7 channel capability is being added to the magnetic tape recorder. The following signals will be monitored on magnetic tape:

Audio Comments	Ground Speed
Time code	Pitch
DFT Frequency (pulse form)	Roll
Vibration (3 channels)	Antenna Acceleration
Drift Angle	Antenna Velocity
VFO Position	Antenna Position
DFT Signal Level (received)	

Several new temperature channels are being added to record temperatures in and around the new transmitter. These new circuits will monitor the following:

Ambient air in missile bay area
Ambient air in pressure vessel
Surface temperature of pressure vessel (inside)
Surface temperature of CFA chassis
Surface temperature of TWT collector
Surface temperature of CFA tube

The CFA current pulse and CFA high voltage will also be monitored.

Fabrication of these mods is 75% completed but calibration has not been started.

SYSTEM

Flight testing was discontinued this month and system modifications were started. Modifications incorporated during this period include:

1. Production type printed circuit boards replace the original Doppler Frequency Tracker breadboard unit.

2. The power supply has been modified electrically to provide regulated 28 volts dc as a primary power source for the

recorder high voltage power supply.

3. The synchronizer has been modified to provide range marks on the system primary film as an aid to film correlation.

4. Mounting for recorder number 6 has been modified to reduce vibration effects. (Recorder number 6 includes modifications incorporated in recorder 4 to reduce vibration).

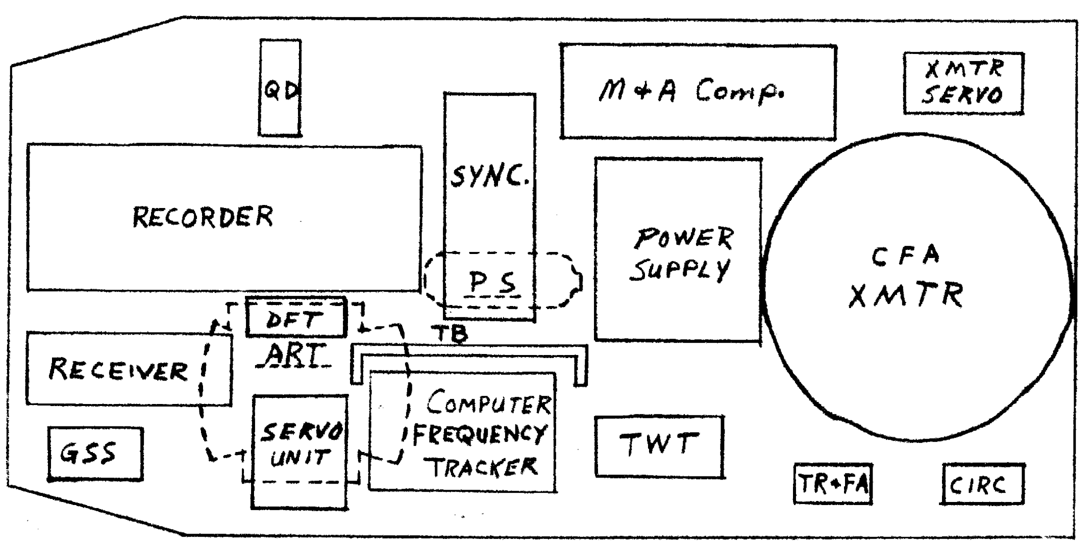
5. The motion compensation mode selector panel has been modified to simplify the radar operator's switching tasks during a data run.

Figure 2 is a sketch of the physical arrangement of system components on the rotary armament door, and Figure 3 is a diagram of the modes of motion compensation available and the switching requirements.

During the down time for radar modification, the aircraft doppler-navigator system and auto-pilot are being overhauled. Also, an aircraft 50 hour inspection is being performed, and minor aircraft skin cracks are being repaired.

B <u>ENVIRONMENTAL TEST</u>

Vibration tests were performed on Recorder #6 with various vibration isolators. In order to use the magnetic vibrator, the cathode ray tube was replaced with a light source. Best results to date were obtained with eight Lord JA 8350-7 isolators. The most range degradation was 3 line widths of a half mil line over a narrow vibration frequency band centered at 140 cps. This frequency caused bad track degradation as well. Vibration in the pitch axis caused the worst film degradation, vibration in the roll axis the least.



QD - Quick Disconnects
GSS - Ground Speed Servo
TB - Terminal Board
TWT - Traveling Wave Tube
TR+FA - TR tube and Ferrite Attenuator
CIRC - Ferrite Circulator
M+A Comp - Motion + Angle Compensation

Located Beneath Door Plates:
ART - APN-102 Antenna, Rcvr, Xmtr
PS - Pressure System

Rotary Armament Door - Equipment Installation

FIGURE 2

SKETCH SHEET
FORM 28577

WESTINGHOUSE ELECTRIC CORPORATION

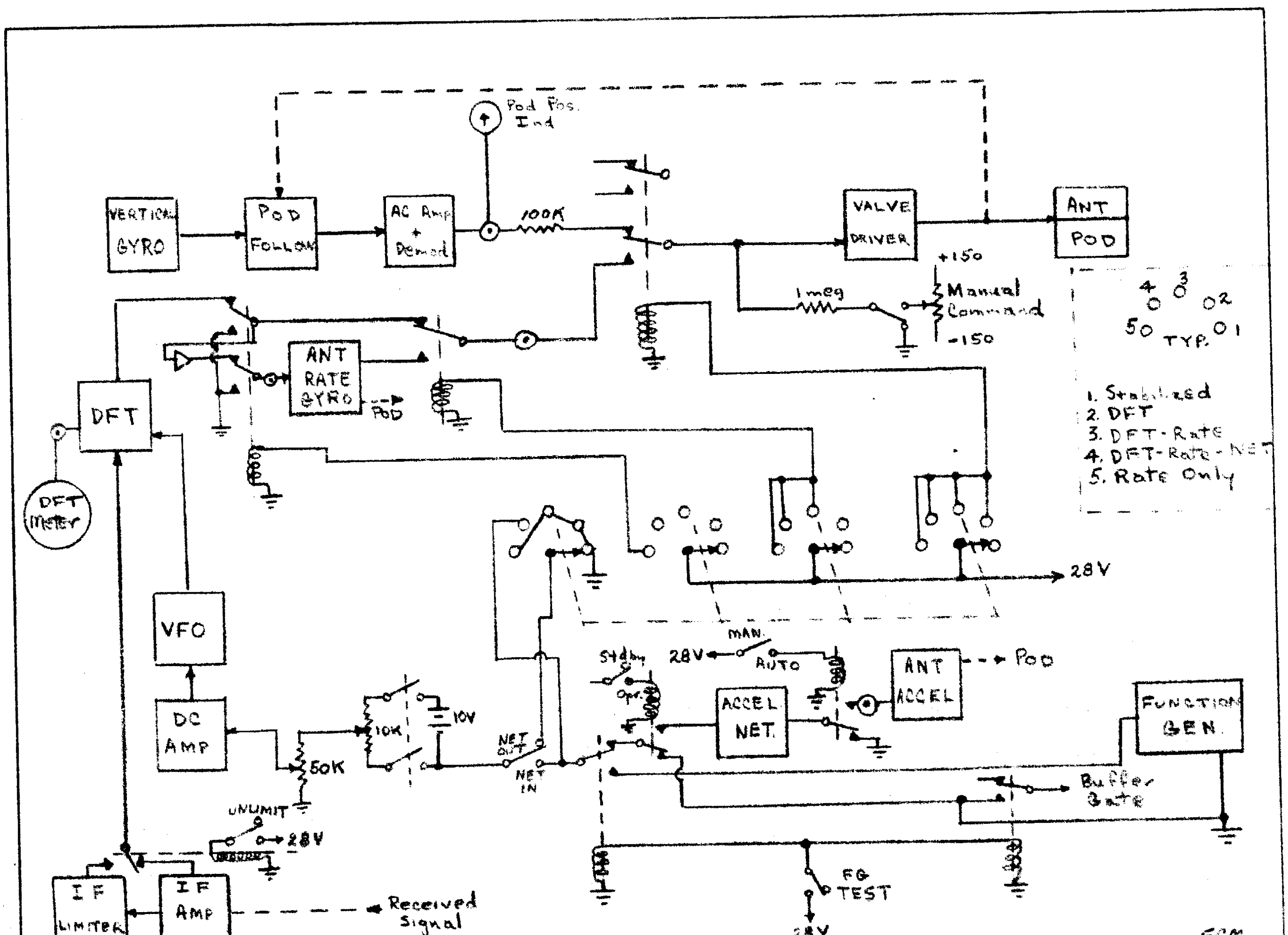

Pod Pos. Ind
VERTICAL GYRO
POD FOLLOW
AC Amp + Demod
100K
VALVE DRIVER
ANT POD
+150
1 meg
Manual Command
-150
4 3 2
5 1
TYP.
1. Stabilized
2. DFT
3. DFT-Rate
4. DFT-Rate-NET
5. Rate Only
ANT RATE GYRO
POD
DFT
DFT Meter
28V
VFO
DC AMP
10K
10V
50K
NET OUT
NET IN
MAN.
AUTO
Stdby
Opr.
28V
ANT ACCEL
Pod
ACCEL NET.
FUNCTION GEN.
Buffer Gate
UNLIMIT
28V
IF LIMITER
IF AMP
Received Signal
FG TEST
28V
FCM
7-25-63

FIGURE 3

Temperature-altitude tests were performed on the modified receiver. Maximum frequency deviation as measured on the LFE Stability Tester was 170 cps during 170 minutes of operation. Maximum drift was 7.5 KC in ten minutes at the stabilized condition of 131°F and 27,000 feet altitude. There was no significant power change during this test.

C <u>DESIGN EVALUATION</u>

The following studies, described in the previous period, were reproduced in this reporting period:

1. Effect of Relative Phase on the Range Resolution of Two Point Targets (STM-126).

2. Feed-Forward (Logetronic) AGC Performance (STM-127).

Other studies underway, but not completed during this period are:

1. <u>Radar Range Equation and Signal/Noise Theory (STM-129)</u>

This study was partly described in the last report, and is a summary of those factors which affect the system signal/noise ratio. This includes the idealized range equation, plus all the system processing losses due to imperfect mechanization. These effects involve not only the radar, but the recorder and correlator as well.

The second phase of the study performed in this period, is a theoretical study of the S/N required for a good map. This was found to be a very complex subject, due largely to the effect of the human observer. Three approaches were studied, and included in the memo, based on:

(a) Data reported in the literature on the sensitivity of the eye in detecting intensity changes.

(b) Detection probability, based on a false alarm probability.

(c) An experiment on target detectability.

Of these, the third appears to best represent the actual case. It differs from the reported experiments in two important ways: the two observed regions of different intensity were noise modulated, and they were physically separated. Both effects were found to drastically increase the required intensity change before it became noticeable to the eye. For no noise modulation and adjacent targets approximately -13 db S/N would suffice. With noise modulation and adjacent targets, -7 db would be marginally adequate. For separated regions with noise modulation, about -2 db is required. To get a really "good-looking" map, it appears that the latter is required.

This study will be issued as a memo in the next period.

2. <u>System Signal/Noise Performance Calculations (STM-132)</u>

The calculations of the expected system S/N, based on the theory of item 1, were completed in this period. A memo will be issued in the next period describing the conclusions and results. Curves of the S/N across the strip were calculated for both area and point targets. Also curves were made for the extreme conditions of offset frequency, corresponding to uncompensated antenna angular motion. All calculations were done for four different altitudes, corresponding to possible modes of operation.

The S/N was found to vary drastically across the strip, due largely to gain-ripple in the antenna pattern and the offset frequency errors due to antenna motion. For example, the peak-to-peak change due to the antenna is about 5 db, and the "average" S/N is -6 db at the highest altitude considered. (This assumes G=31 db, Ppk=1 mw, and a TWT receiver.)

Two spatial filter methods were considered for the correlator:

(a) A wide one consisting of 2 knife edges, wide enough to always pass the signal, even with maximum offset variations.

(b) A narrow one, with a Taylor weighting transparent mask at the Fourier plane. (The weighting is necessary to prevent excessive side-lobes when the narrow filter is used). The narrow filter was found to be greatly superior in minimizing the S/N variation across the strip due to offset frequency changes, and was the approach assumed in the S/N curves.

3. <u>Fourier-plane Weighting Mask</u>

As a direct result of the above study of the effect of a weighting mask on system signal/noise, many advantages of such a mask became apparent. First, the S/N is improved at all ranges, because the filtering approaches the "matched-filter" optimum. Second, the variations in S/N across the strip caused by offset frequency changes are reduced because the effective offset variation is greatly reduced. Third, the correlation clutter of strong point targets is greatly reduced, since the minimum offset frequency is increased. Lastly, the system resolution should be improved, as discussed under the next report.

Quantitative figures for all the effects have not yet been completed, and will be the subject of a continuing study. It does appear clear that a Fourier-plane frequency weighting mask is extremely important, and it is recommended that the procurement of one be expedited.

4. System Resolution

The effect of correlating only a fraction of the signal history on resolution was considered. It was found that most of the degrading factors on resolution become less, as the fraction is made smaller. The only factor getting worse is the inherent focussed spot size of the hologram. Combining all the contributing factors gave a curve of resolution versus fraction - processed, which had a minimum value at about 1/3 to 1/2 of the signal. That is, the resolution should actually improve, as less signal is processed. For the resolution to equal that for the full signal, only about 20% need be correlated.

These conclusions support the desirability for a spatial filter mask discussed above, and perhaps also help explain a similar effect noted experimentally.

Based on processing one-half the signal, a rough revised resolution budget was made, updating the one made last January. Further work is required to include second-order effects.

D ANTENNA

All major design work is complete. The work remaining is the final report, R.F. testing of No. 2 and No. 3 antennas, R.F. evaluation of a radome sample and completion of the six spares modules. Some "clean up" work on the drawings is also necessary.

A fixture is being fabricated to enable the bonding of a new laminate on an array stick without removing the array stick from the module. If tests are successful, this fixture will provide a repair technique for the most probable failure.

PARTS STATUS

Antenna No. 2 - Complete. More range testing is desirable for this antenna.

Antenna No. 3 - Complete except for R.F. range testing. This antenna will be available for environmental testing on 5 August 1963.

Spares Modules - All six modules bonded and assembled. Three modules have been soldered, pressure tested and R.F. tested.

E RECORDER

VIBRATION

During July, attempts were made to reduce vibration resonances within the recorder and noise generated by rotating components.

Excitation was introduced by a speaker attached directly to the bearing plate with varying frequency and amplitude of the driving cone. Signals from accelerometers placed at suspect locations were observed on an oscilloscope. This technique allowed faster evaluation of a comtemplated design change, and photographs were taken for comparison of results. Highest responses were found at 218 and 285 cps on the plates and anything spanning the plates, such as the lens board or tie-bars. Several layers of cork rubber composition isolating the lens mounting and M3 mirrors from the lens board proved ineffective below 300 cps.

A layer of cork rubber between the motors and the plates and the use of nylon screws reduced noise by approximately 50%. The residual noise was reflected through the plates onto the lens board and the lens and the M3 mirror. After isolating the drive system, an accelerometer placed on the side plate indicating motion along the optical path showed 10 micro-inch motion at the predominant frequency of 485 cps. The predominant frequency was determined by feeding the accelerometer signal through a band pass filter to a spectrum analyzer. The amount of noise or vibration is still excessive and effort is continuing to reduce it.

ELECTRICAL

Packaging of the modified focus modulation circuit has been started.

The variable speed inverter for film drive does not bottom at 350 cps when the output of the navigational potentiometer moves below the control voltage for this frequency. An additional circuit, now in fabrication, provides a "stop" for the low frequency excursion at approximately 350 cps.

The neutral density wedge method of measuring frequency is being used in the study of the vibration and noise problems with some success. More intensive work on this will be conducted in the next month.

A circuit to provide a Raster sweep has been breadboarded to observe hum, jitter, and other disturbances when used in conjunction with a dot generator and the viewing microscope. This circuit drives one of the 500 ohm centering coils on the yoke with a back-to-back sawtooth to produce a raster. Intensity modulating the CRT grid with a dot generator produces a time pattern which can be used for adjusting focus and viewing disturbing hum fields.

KAISER HIGH VOLTAGE SUPPLIES

The first Kaiser high voltage supply has been installed in Recorder #6 at Westinghouse. Regulation of output voltage with temperature variations is satisfactory, but line regulation does not meet specification. The power supply will eventually be returned for repair.

The second and third supplies have been received at Itek and are undergoing Phase II of the Acceptance Tests. The second supply, on which the Phase II tests are 90% complete, can hold the ratio of ultor to focus voltage better than $\pm$ 0.1% for a period of 1 1/2 hours after a 30 minute warm-up. During this interval in a 24^{o}C ambient, the transistor heat sink temperature increased from 29^{o} to 60^{o}C. Line and load regulation is better than $\pm$ 0.02% as the baseplate temperature changed from 37^{o} to 33^{o}C. Ripple on the ultor and focus voltages is less than $\pm$ 0.1% and locked to the input synchronizing square wave.

A maximum external magnetic field of 7.5×10^{-3} gauss is radiated 3 inches from the top of the supply next to the low voltage plug. A step function from no load to full load on the focus supply produced a 2 volt overshoot.

Further dynamic testing in the recorder is required to complete the Acceptance Test. In addition, vibration tests and a temperature check will be made, when sufficient operational power supplies are available.

F SWITCH TUBES

One of the two new WX-3846 tail bite tubes, was returned for retest because of the inability to control the firing point with respect to the rf pulse. Internal pressure apparently dropped due to a leaky valve. The tube was refilled to 8 PSIG pressure, tested and returned to the system, where it is now operating satisfactorily. The second WX-3846 has been tested and packaged.

Four new WX-4554 dump tubes have been fabricated to date. The flattening of the electrodes to reduce erosion proved to be ineffective. One tube had rhodium tips on the domes while the other tubes had tungsten tips. The rhodium tips did not form burrs in the erosion process like the tungsten tips, but eroded evenly over the surface. The rhodium tips autotriggered at 40 KW peak whereas the tungsten tips showed no autotriggering up to 60 KW peak.

The above tubes were tested on the traveling wave resonator ring. The data has been compiled and is now being analyzed. The breakdown time of the above tubes was measured to be less than or equal to 5 nanoseconds to the 3 db point. Isolation was between 10 and 13 db.

G SYNCHRONIZER

SYNCHRONIZER BOX

Change orders have been written to change both wiring diagram and schematic diagram to conform to latest configuration. A Range Mark Generator has been readied for the flight test system.

FREQUENCY GENERATOR

90% of circuitry has been designed and breadboarded. These breadboarded units will be mounted in the Environmental frequency generator chassis and checked out for use in the F101 flight test program. The present flight test unit and the Evaluation unit will then be reworked by Model Shop for shipment with systems.

An entirely new center chassis has been laid out to replace the original. Drafting has started detailing. Printed circuit boards are about 30% completed by drafting.

H TRANSMITTER

FLYING BREADBOARD

Additional cooling was added to the CFA chassis. Specification checks and measurements of power output, phase stability and jitter were performed.

The charging choke failed after 10 minutes. It was found to have a manufacturing defect. The second delivered unit has operated satisfactory for about 20 hours.

Three 30 KV power transformers have failed by arcing across the winding. A new epoxy molded design has operated but the results are still inconclusive.

PROTOTYPES

CFA chassis position was changed to increase distance between ground plane and thyratron tube.

Electrical changes found necessary from the breadboard were incorporated into the units. Wiring was completed as far as mechanical conditions would allow. Unit was circuit checked.

I FIELD TEST EQUIPMENT

The modifications of Stability Analyzer are completed and Preliminary checkout indicates that the problems have been satisfactorily solved. The residual instabilities of the Test Equipment have been reduced across the entire frequency spectrum of interest (0 - 200 cps) and the linearity is now within 1% over a frequency range of 1800 cps. See Figure 4.

Composite tests are now in progress. However, the phase lock problem of the VFO and intermediate Test Set Frequencies has not yet been eliminated. Changing of the Grounding System has reduced the problem somewhat but further investigations are required. It is felt that the problem is still severe enough to cause some nonlinearities in the Doppler sweeps.

No tests have been performed with the system.

All of the Standard Test Equipment has now been received. The Jitter Tester and Sub-sonic Analyzer are still in calibration.

J MOTION COMPENSATION

The final mechanization for the motion compensation as completed by Honeywell has a resonant response. The resonant frequency and damping are such as to give the required integration accuracy but result in a long settling time. This problem is solved by decreasing the settling time by about 5 at turn on, and then switching to high gain, high accuracy, for mapping. The theory of this design has been checked and considered good.

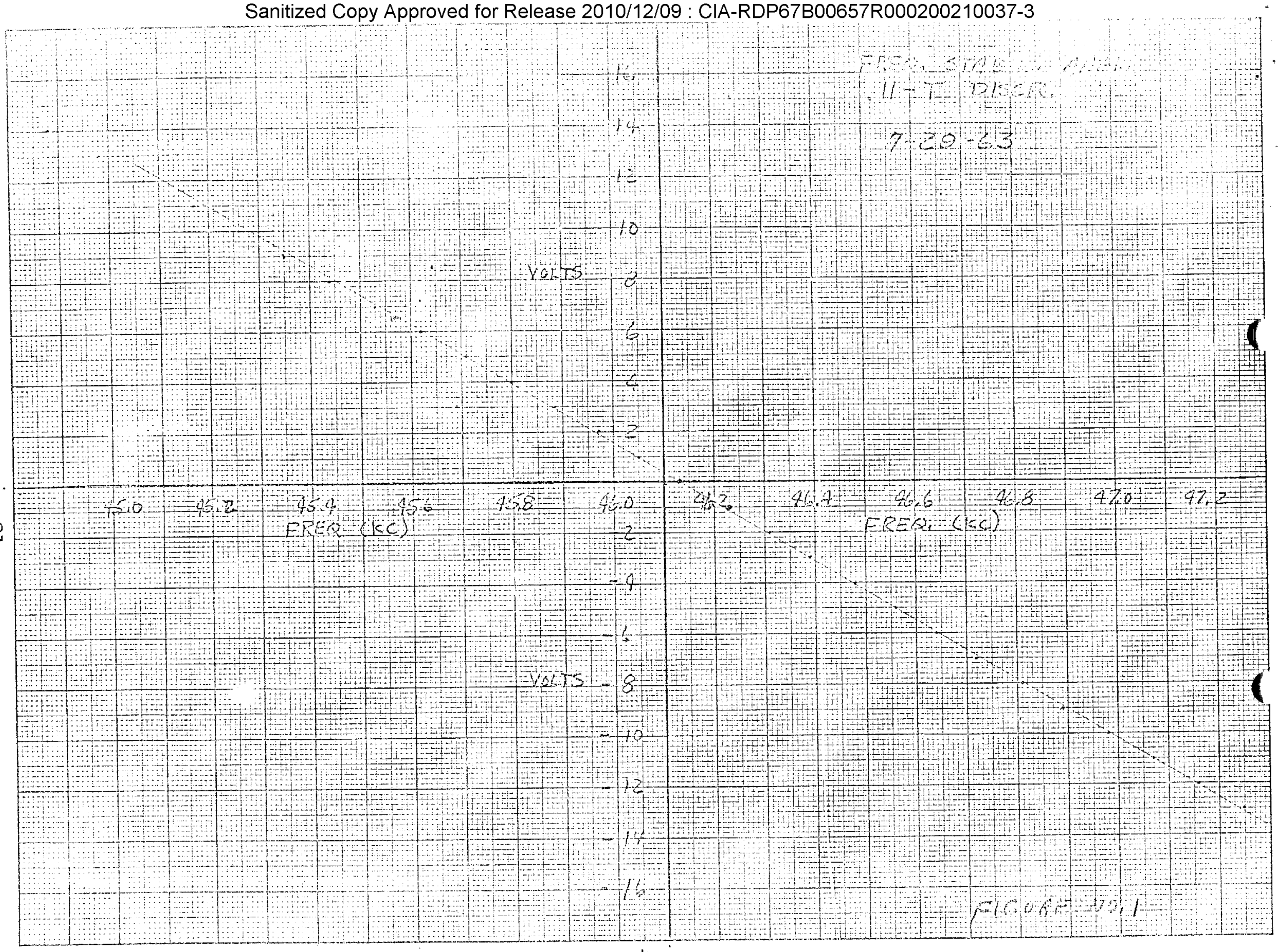


FIGURE 4

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K RADOME

A sample of the new silicone glass radome was received in a panel large enough to test one module of the antenna. The loss at most was .5 db, occurring at a depression angle corresponding to maximum range. From this it was determined that the thickness could be increased from .300" to .306" giving a predicted loss of .2 db maximum. From electrical considerations the tolerance should be ± .002" but this may be tighter than can be conveniently maintained.

This radome performance is considered good. It is much better than originally assumed and rather negligible compared with the loss due to antenna blocking by metal support structure for the radome itself.