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I. INTRODUCTION

In October 1963, the Bell Aerosystems Company received a contract from NASA- Manned Spacecraft Center, Flight Crew Support Division, NAS 9-2041, to built an Agena Target Image Generator. This device was delivered, evaluated, and used by NASA on a part task trainer.

In July 1964, this contract for GEOS, NAS 9-2988, was let to Bell Aerosystems to add an earth to the scene and inset the electronically generated target into this scene. The earth generator portion of the system was a radically new concept utilizing the general principle developed in the target generator, but extending these through the use of a variable frequency scan arrangement that would increase the resolution by providing approximately 2000 scan lines from one horizon to the opposite horizon. The GEOS system was also new, in that, it would provide color features through a flying spot scanner, and target insetting by the use of recording storage tubes. Further, the system required new high frequency 21" magnetically deflected displays that could be registered adequately to provide a color scene. In all three of these areas, new developments were necessary and the state-of-the-art was being extended as follows:

a. In Variable Frequency Scan, it was necessary to vary scan frequency over a 7.5:1 range, simultaneously modulate and maintain a constant 90° phase shift between two scan signals over this frequency range.

b. In the flying spot scanner, video amplifier development was necessary to compensate for the phosphor persistence problem of P-24 phosphor, which is about 1.5 usec to 10% brightness. This compensation through proper high frequency peaking was needed to obtain the video band pass of about 17.5 MC.

c. The target insetting required the use of a new recording storage tube, the Raytheon CK 1500, that had the capability of being cycled through write, read, and erase in 16 millisecond periods. Also a three cycle program had to be used rather than the normal four cycle program of prime, write, read, and erase.

d. The displays had to be large screen oscilloscopes with a spot velocity capability of at least an 1"/usec which was twice that available in any previous equipment. In addition, two complementary phosphors had to be used on two tubes to obtain the approximate colors seen from orbit. Film for the scanner, proper color separation and combining dichroics, and the phosphors had to be chosen and tested for this color display. High brightness on the displays was necessary to make up for the 100:1 loss through the infinity optics system to which the displays would be attached.

During the course of the contract, additions were made to adapt the system to the Gemini Full Mission Simulator. These included the addition of right window displays with appropriate window axis transformations, multiplexers, right window insetting, etc.

It also included a "back transformation" to provide transformed offset signals for the displacement of the two pilots; a new right window target video system, since the back side blanking and shading for each window is different; and servoed instead of manual target attitude transformation.

II. DESIGN APPROACH

A. Scanning and Computing System - The proposed approach was to design a scan generator where the scan was earth related but also oriented in accordance with the heading of the spacecraft. In this system, the whole earth cap from horizon to horizon would not be scanned, but only the portion ahead of the vehicle.

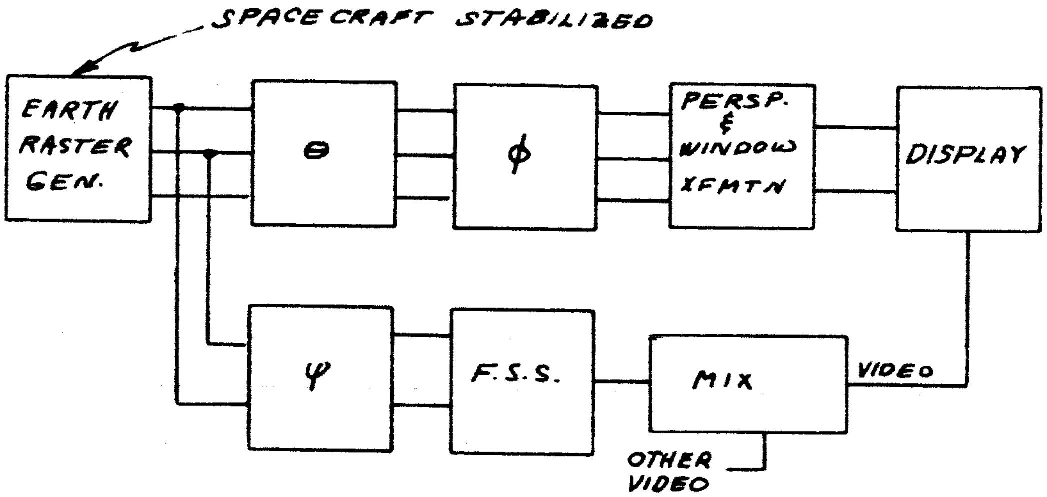
This system required spacecraft angles from the NASA computer defined in a ψ, θ, ϕ sequence.

An early meeting with NASA personnel resulted in change to the θ, ψ, ϕ sequence due to unavailability of the other angles. This forced us to scan the whole earth cap below the vehicle and ultimately resulted in a lower resolution in the system than originally intended, even though we didn't expect the resolution drop at the time the change was made.

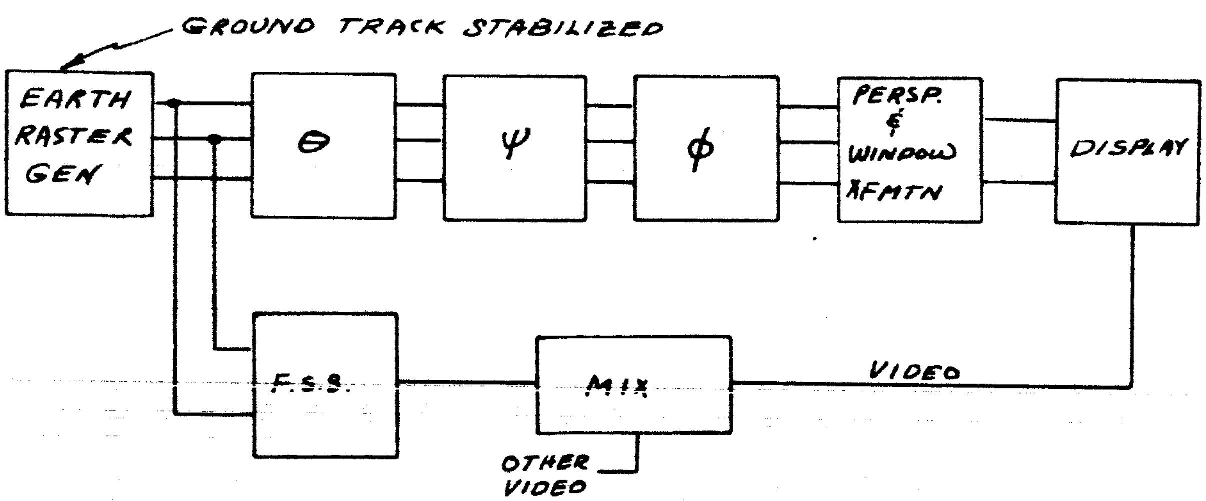
The resolution decrease comes from the fact that time is wasted scanning areas of the earth beyond the immediate window field of view.

Figure 1a shows the general scan and computing scheme for both methods described above. It is apparent at this time that the former method would have been preferable and future resolution improvements in the system should include a change to that method if possible.

Figure 1b is the computing system function for GEOS as it presently exists.



ψ, θ, ϕ Gimbal Order



θ, ψ, ϕ Gimbal Order

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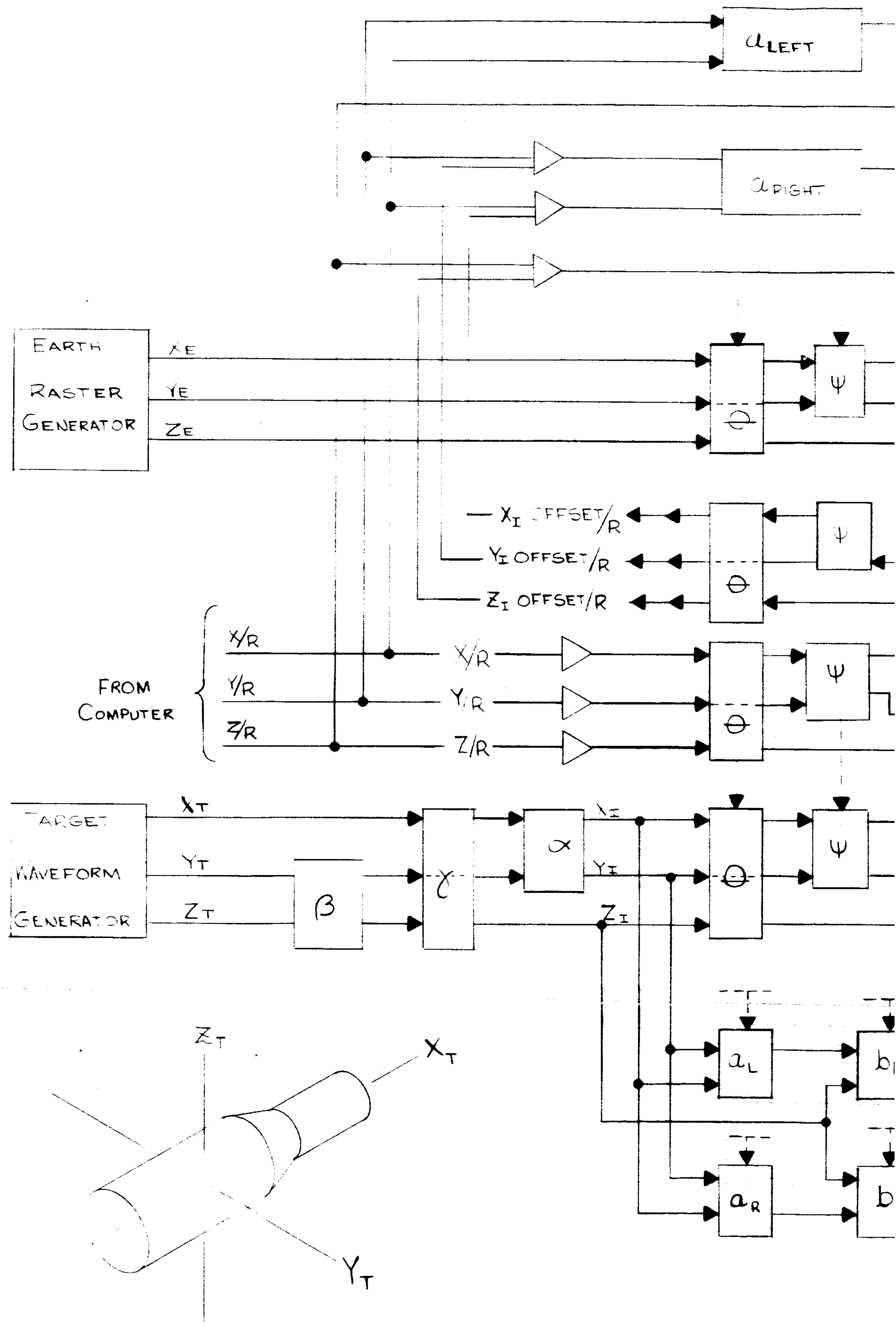
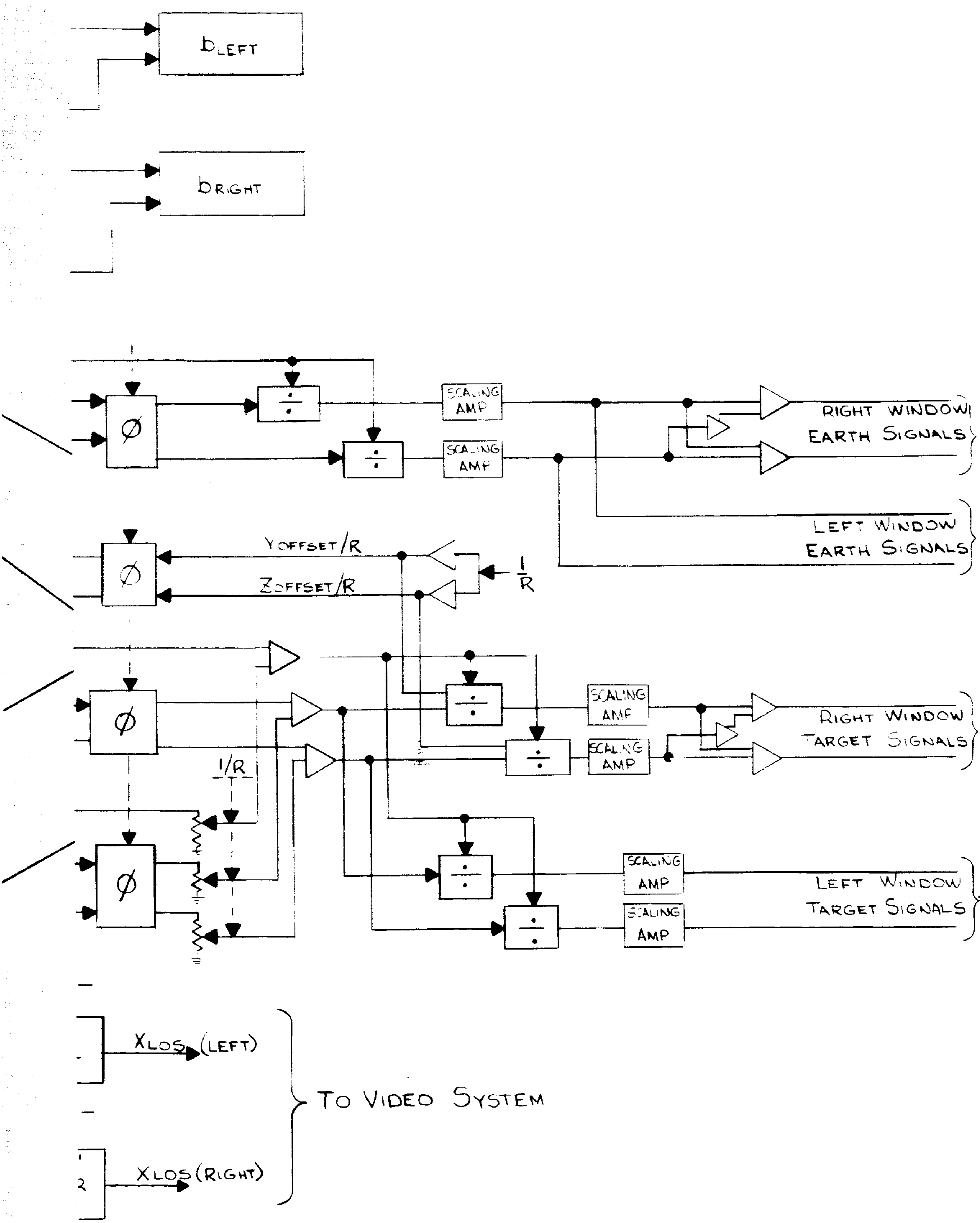
Figure 1a



a_{LEFT}
a_{RIGHT}
EARTH
RASTER
GENERATOR
X_E
Y_E
Z_E
Ψ
Θ
X_I OFFSET/R
Y_I OFFSET/R
Z_I OFFSET/R
FROM
COMPUTER
X/R
Y/R
Z/R
TARGET
WAVEFORM
GENERATOR
X_T
Y_T
Z_T
β
γ
α
X_I
Y_I
Z_I
a_L
a_R



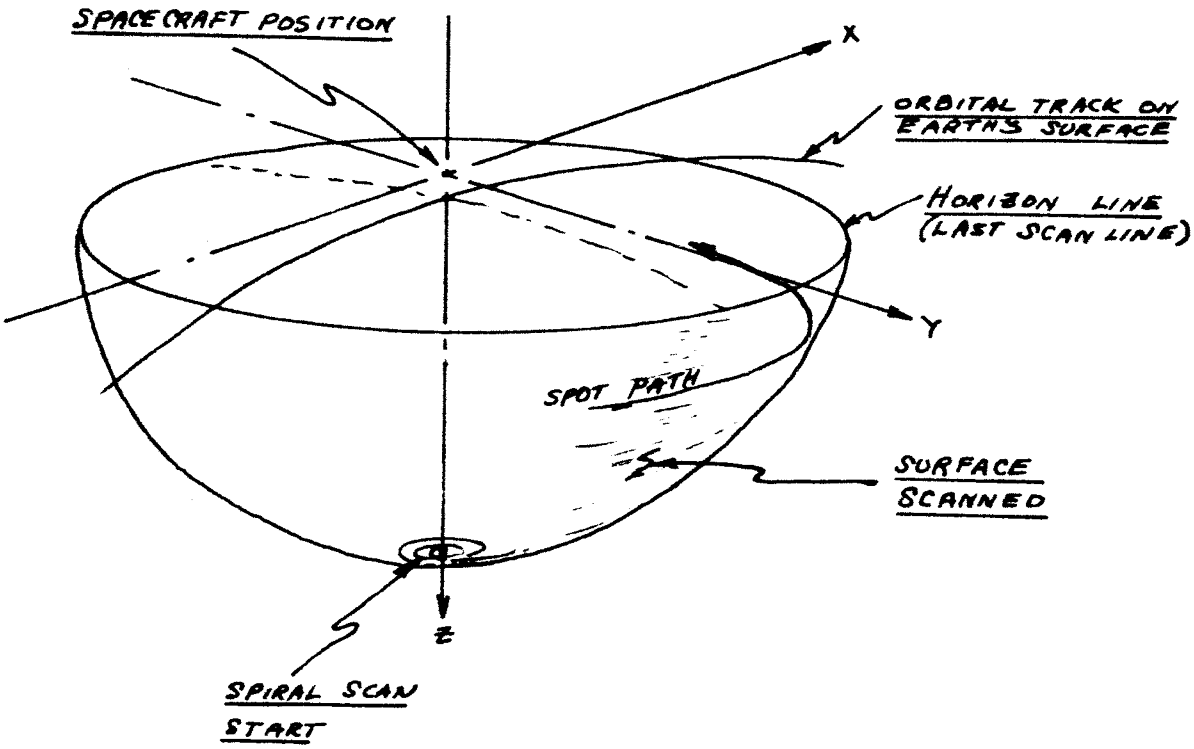
b_{LEFT}
b_{RIGHT}
SCALING AMP
SCALING AMP
RIGHT WINDOW EARTH SIGNALS
LEFT WINDOW EARTH SIGNALS
Y_{OFFSET}/R
Z_{OFFSET}/R
$\frac{1}{R}$
SCALING AMP
SCALING AMP
RIGHT WINDOW TARGET SIGNALS
1/R
SCALING AMP
SCALING AMP
LEFT WINDOW TARGET SIGNALS
X_{LOS} (LEFT)
X_{LOS} (RIGHT)
TO VIDEO SYSTEM

II. B. Earth Raster Generator - A variable frequency, variable amplitude scan generator was built to produce the three components (x, y, and z) of a scanned spot's position in three dimensional spaces defined in a rectangular coordinate system. The spot scans from the Nadir (point directly below the spacecraft) to the horizon in an Archimedes spiral consisting of approximately 1000 revolutions. In order to keep the spot velocity constant, the radial velocity must be decreased in accordance with $\frac{1}{r}$ where r is the instantaneous radius of the spiral.

Instead of actually moving this spot on the earth's surface, it is moved over a surface as shown in Figure 2. This was initially done to keep the spot at constant range from the spacecraft with the intent that the perspective division could be eliminated. Later the divider had to be installed anyway and the functions were not changed because it reduced the necessary range of operation of the divider.

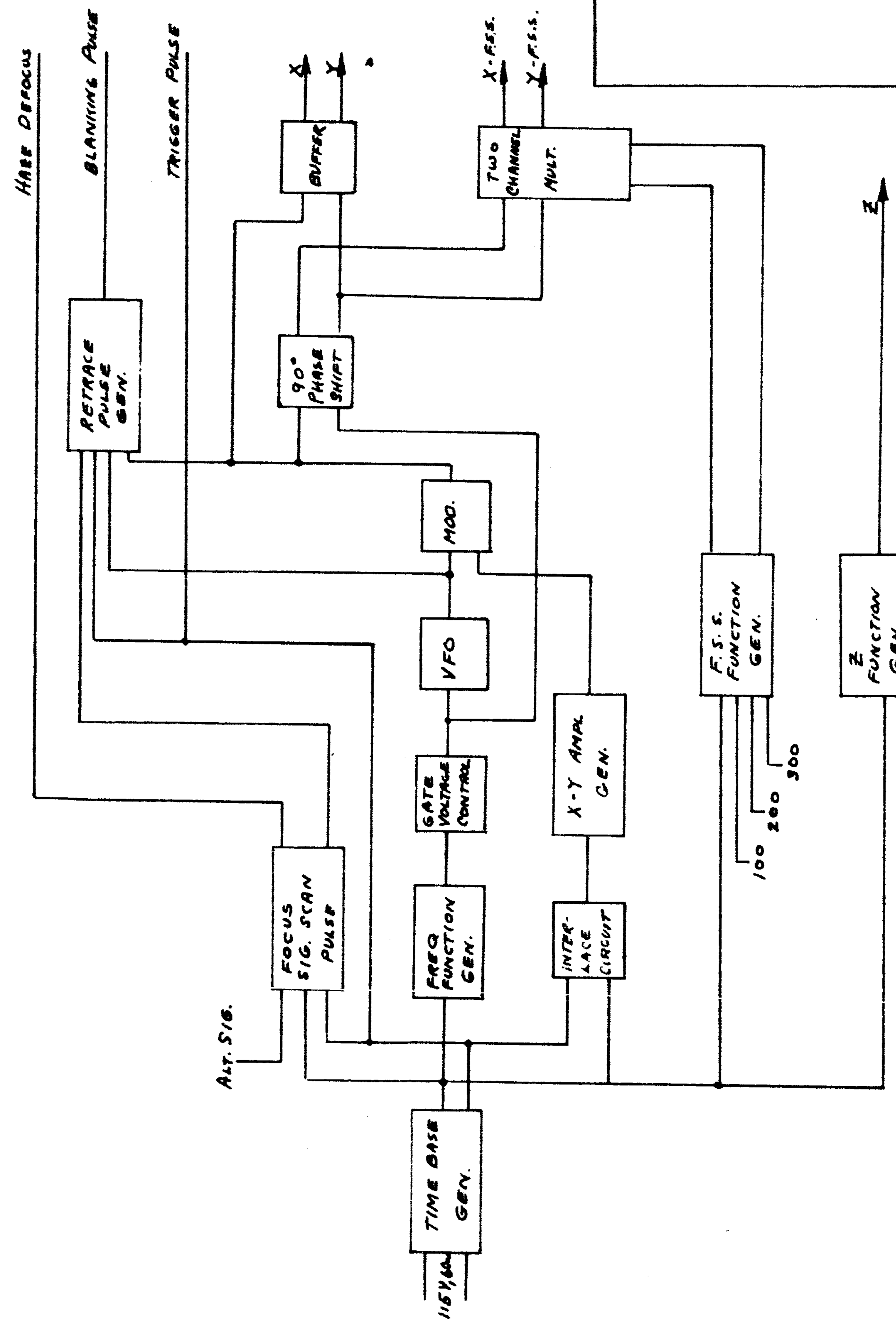
To obtain signals for the flying spot scanner, the x and y scan signals transformed from this spherical surface to the earth surface. This is done with a multiplier inside the earth raster generator.

Functionally, this scan generator is shown in Figure 3. The heart of the system is the VFO (Variable Frequency Oscillator), Modulator, and 90° phase shifter. These devices are controlled by a time base generator, a frequency function generator and a control circuit that compensates for nonlinearities in the VFO and phase shifter. The time base generator is simply a integrating type sawtooth generator which is reset with a pulse developed from the 60 ~ line. This pulse becomes the trigger for the whole system of blanking and multiplexing. The frequency function generator is especially designed in conjunction with the x - y amplitude generator and the z function



SCANNED SURFACE IN GEOS

FIGURE 2



VARIABLE FREQUENCY SCAN GENERATOR
FIGURE 3

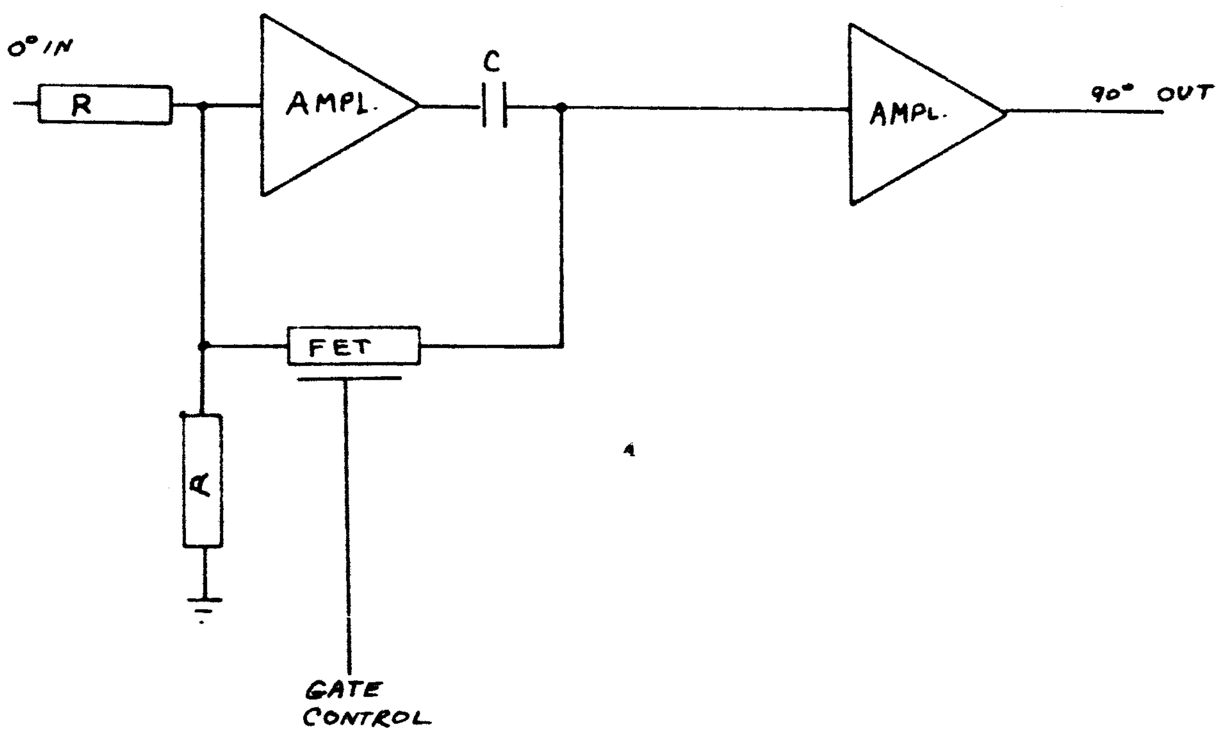
Form 0179

generator to obtain constant spot velocity in the Archimedes spiral while maintaining proper line spacing.

It should be noted that a separate Flying Spot Scanner (FSS) function generator is used with a two channel analog multiplier to transform the x and y outputs to the earth's surface for picking up data from the film. Thus two sets of x - y signals come out of the raster generator.

The variable frequency oscillator is basically a phase shift oscillator where the frequency is controlled with Field Effect Transistors (FET) on the inputs to two integrating D.C. amplifiers. Thus, as the gate control voltage is increased, the FET resistance increases and the frequency drops. The circuit includes compensation networks for linearity and for maintaining near constant amplitude.

The 90° phase shifter uses the same gate control voltage to another FET used to maintain 90° phase shift over the frequency range. Figure 4 illustrates the circuit, which consists mainly of an inverting amplifier and an R-C summation of the 0° signal and the 180° signal to obtain the 90° phase. As long as the R and C are maintained at equal impedance for over the range of frequencies, the phase will remain 90°. The modulator in the system is really a four quadrant analog multiplier of unique design.



VARIABLE FREQUENCY 90° PHASE SHIFTER

FIGURE 4

Figure 5 shows a general block diagram of this type of device.

$$\frac{e_1}{R_1} = \frac{e_2}{R_{D_1}} \tag{1}$$

$$R_{D_1} = \frac{R_1\, e_2}{e_1} \tag{2}$$

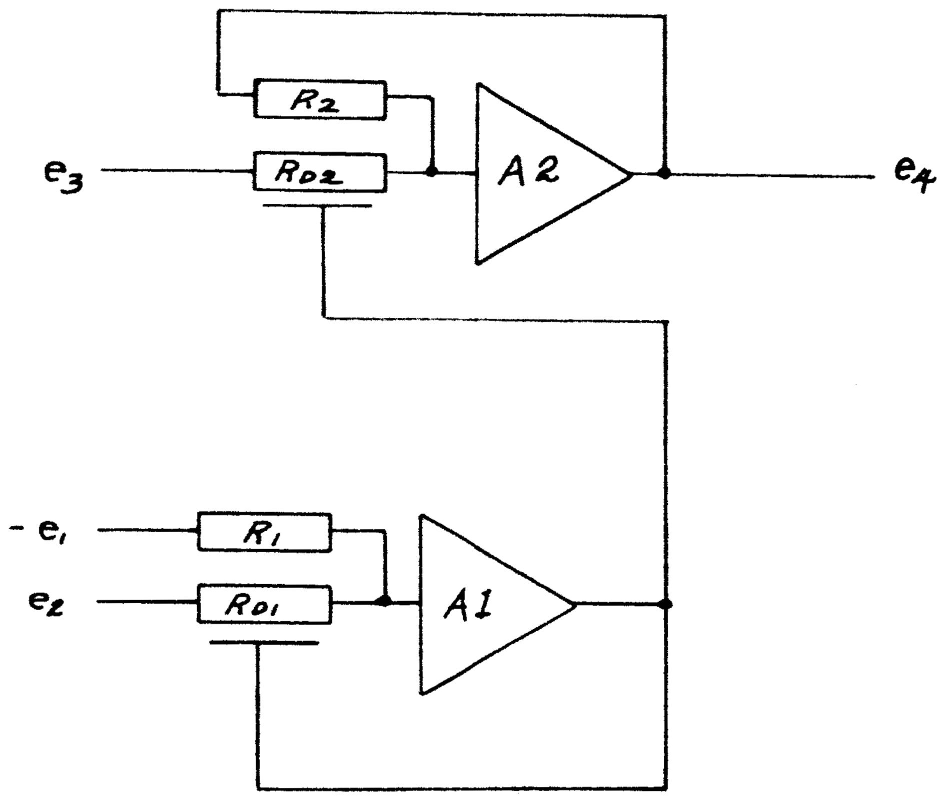
$$R_{D_1} = R_{D_2} \quad \text{when properly controlled and matched} \tag{3}$$

$$e_4 = \frac{R_2}{R_{D_2}}\, e_3 \tag{4}$$

Substituting (2) in (4) we have

$$e_4 = \frac{R_2\, e_1\, e_3}{R_1\, e_2}$$

As a multiplier, e_2 is held constant. Also an additional offset is inserted into the amplifier A1 to obtain four quadrant operation. This D.C. offset is subtracted out on the output of the divider.



MULTIPLIER - DIVIDER

FIGURE 5

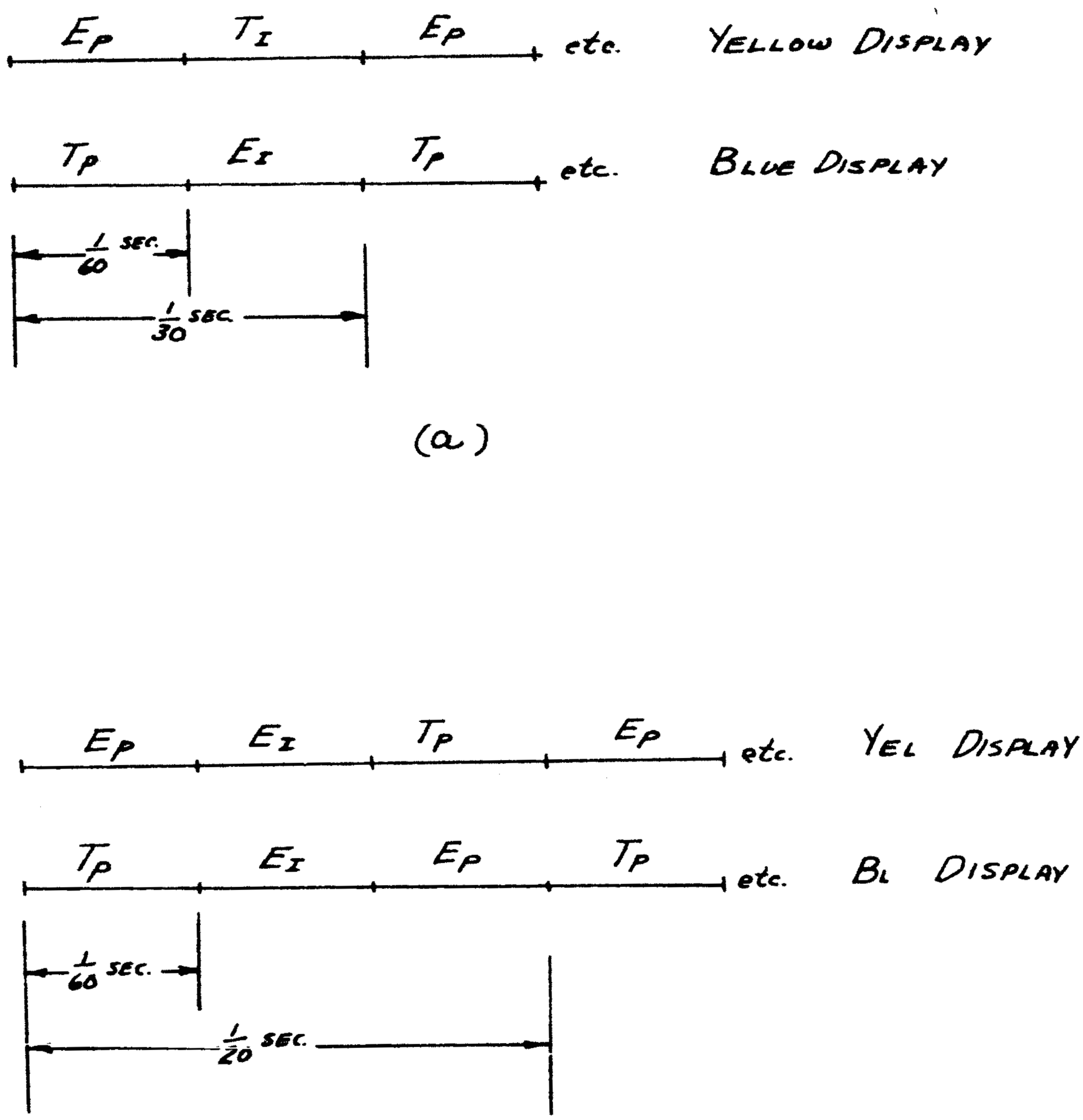
II. C. <u>Multiplexing</u> - Early in the program a choice of P11 and P20 phosphors were made for the displays. P11 is chemically composed of ZnS:Ag (Ni), is of medium short persistence, and fluoresces blue. Its absolute efficiency is 0.10 and produces 140 lumens per radiated watt. P20 is composed of ZnCdS:Ag, is of medium persistence and fluoresces yellow-green. Its absolute efficiency is .14 radiated watts per input watt and it produces 480 lumens per radiated watt.

Experiments were performed to determine whether these phosphors were actually complimentary as data indicated and what relative input wattage was necessary to obtain white.

Utilizing a Liberty Owens 90-650 dichroic coating for image combining, it was found that nearly equal input wattage could be used. Under this condition, white was obtained with P20 operating at 64 foot lamberts per input watt but P11 produced only 13.5 foot lamberts per input watt. On an oscilloscope test setup, we found that the apparent line resolution dropped in half because of this great difference in relative brightness. The blue lines did not appear as separate distinct lines but only colored the yellow lines to white. We had proposed a multiplexing system as shown on Figure 6 a, where earth prime scan was put on one color and earth interlace put on the other.

The test data indicated this would give us an apparent resolution of one half of the actual number of scan lines because earth interlace would never be put on both displays.

We saw no easy way out except that possibly a staggered arrangement could be used with a 20 cps rep rate (see Figure 6 b) where the flicker frequency would be changed to 20 cps instead of 30. It appeared feasible on the



MULTIPLEXING

FIGURE 6

Form 0179

basis that the duty cycle for earth information was nearly 100%. This possibility was built into the multiplexing system so the final system could be operated either way. During checkout at Bell, the staggered system was checked first. The earth looked fairly good, but the target flickered badly, especially at close range. Some 20 cps flicker could also be seen on the earth. As a result, we rejected this approach and wired the system as originally planned, but with the resulting apparent resolution loss.

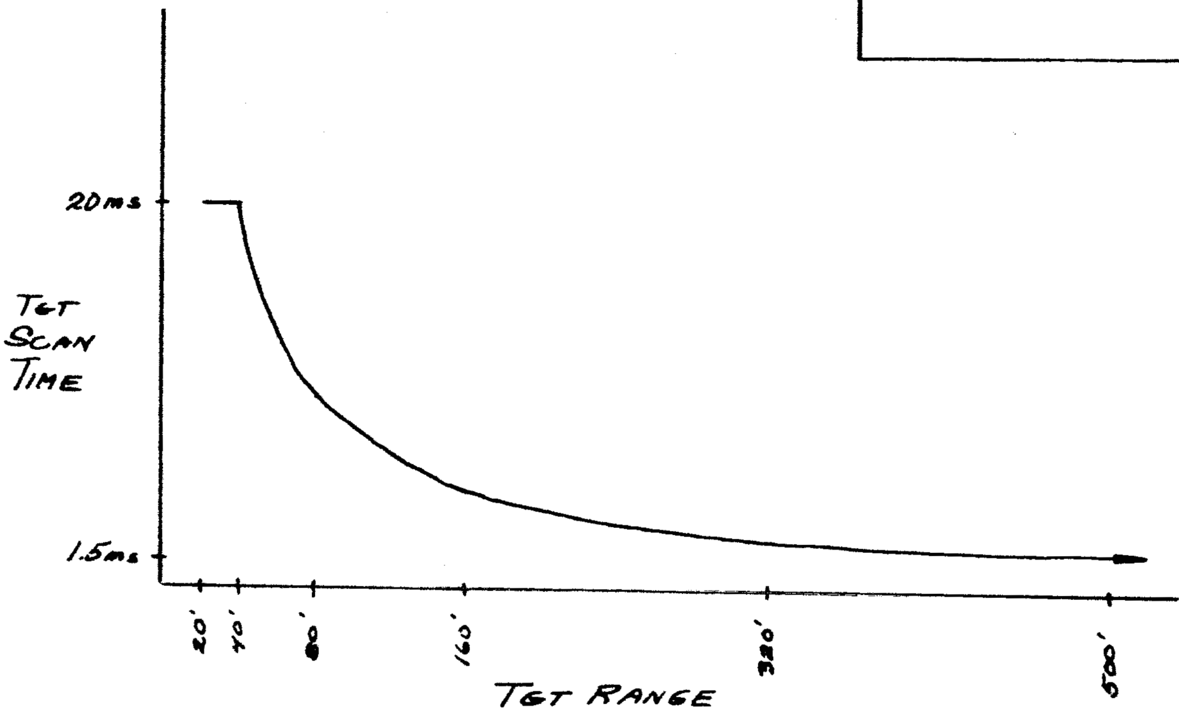
Recent thinking on the system has resulted in a way of increasing the resolution by variable time sharing dependent upon target range. Presently 16 milliseconds are used for target and earth regardless of target size or target range. In an image related scanning system, this results in better resolution on the target than is necessary at greater ranges. The number of target scan lines were originally set up to give good resolution at the closest range. If target range is increased by four, the resolution is now four times better than necessary. Thus, we would now propose to reduce target scan time with increased range in accord with a function approximately as shown on Figure 7a.

Earth scan time would also be varied to reduce the number of scan lines when the target is at close range. This can be justified if one considers that at close target range, the astronaut's prime interest is with the target, and the earth is only a background reference.

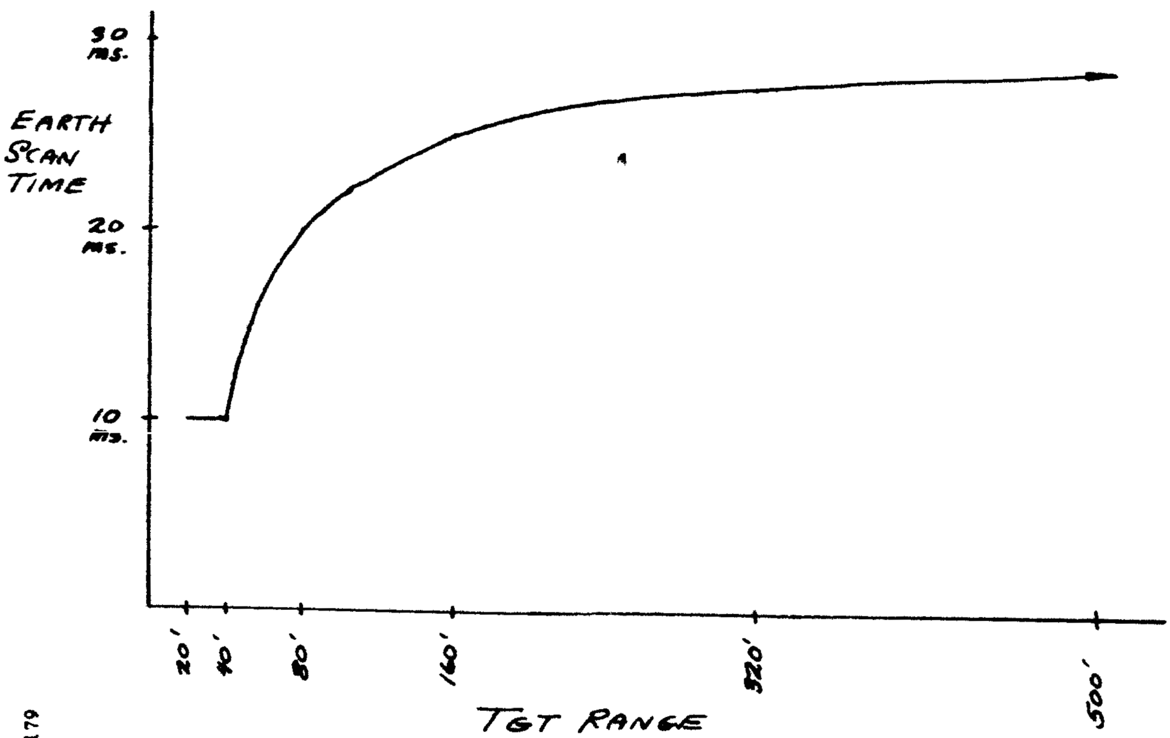
The earth would also be defocused at this close target range to reduce the effect of the scan lines. Earth time would vary as in Figure 7b.

Any future resolution work that is done on GEOS should probably incorporate this concept.

By C. M. Whitty Date 12-10-65 | BELL AEROSYSTEMS COMPANY | Model ____ Page 16
Checked ____ Date ____ | | Airplane ____ Report 60009-517



(a)



(b)

FIGURE 7

Form 0179

II. D. Flying Spot Scanner System (FSS)

1. General - The Flying Spot Scanner System involves deflection amplifiers, a 5" magnetically deflected CRT; an optical system consisting of an imaging lens, condensing lens, and dichroics; two photo multiplier with appropriate dynode circuitry, phosphor compensation, pre-amplifiers, video amplifier, high voltage supplies, a focus regulator, and blanking circuitry for the FSS CRT.

We were particularly concerned in the design phase with phosphor choice and photo multiplier pre-amplifier design. The phosphor had to be in the visible spectrum because GEOS was a color system. Also the phosphor had to be short persistence. The phosphor best fitting the bill was P24. It has a decay to 10% brightness in 1.5 usec. Normal P15 or P16 ultra violet phosphors used on Flying Spot Scanners decay to 10% in 0.12 usec.

It was extremely difficult to design the persistence compensation circuitry to obtain the necessary bandpass for the whole system. High frequency peaking was necessary, but this had to be accomplished in such a way that signal to noise ratio could be kept high.

The final video system performed very well, however, and we were able to obtain the required bandpass without objectionable video noise.

2. Video System Design Approach - Resolution bandpass requirement on the final display is calculated by the formula:

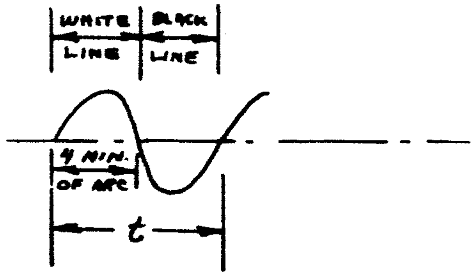
$$f = 0.5 \frac{V_s \theta}{H A_c} \ mc$$

where V_s = spot velocity in inches per usec.

θ = field of view of GEOS in degrees.

H = horizontal length of display in inches

A_c = visual acuity (nominal) in degrees.



The derivation is based on the standard TV line pair as shown at left where

$$f = \frac{1}{t}$$

$$\therefore f = 0.5 \times \frac{.75}{\text{usec}} \times 90 \times \frac{1}{19} \times \frac{60}{4} = 26.6 \text{ mc and } t = 37.6 \text{ nsec}$$

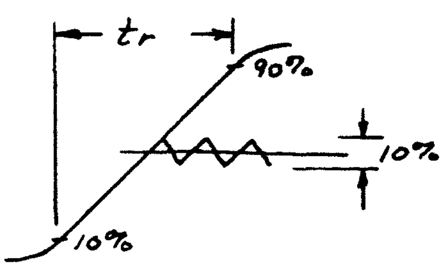
The design aim was that this frequency occuring at 10%, the maximum amplitude capability of the video system would produce the required resolution.

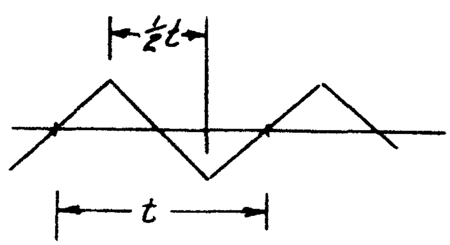
Correlation of this point to the 3 db point of the system amplitude response curve is difficult without knowledge of the curves of individual amplifiers in the video chain. However, an approximate correlation can be made to the rise time characteristic of a video chain.

The transient response of a good video system has minimum overshoot or smear. The transient response is shown below. If the <u>assumption</u> is made that the sinusoidal response above can be approximated by the triangular response shown, then the term $\frac{1}{2}$ t is 10% of the rise time.

$$\frac{1}{2} t = \frac{37.6}{2} = 18.8 \text{ nanosec}$$

or $t_r = 10 \times 18.8 = 188$ nanosec $\approx$ 0.19 microsec





The actual frequency response of the system is of little consequence in the final analysis. Good transient response with negligible time delay distortion is the first requirement for a good video chain. The design approach then is to obtain a system capable of $t_r = 0.19$ usec with no overshoot or smear.

3. Photomultiplier Subsystem - The RCA 7326 photomultiplier tube was chosen for its spectral response (S-20), noise characteristic; also external focus capability for optimum performance.

The FSS tube phosphor decay curve was analyzed. Compensation for the decay can be realized with three RC time constants for high frequency peaking. A rise time of 50 to 80 nanoseconds was theoretically realizable with high frequency peaking resulting in a ratio of H.F. gain to low frequency gain of twenty to one in the video system.

The main noise components in the system are:

a. The photomultiplier noise due to signal (this is not the same as dark current noise).

b. Phosphor noise due to granular structure of the tube surface.

A theoretical signal to RMS noise ratio of thirty to one was calculated. Previous experience shows that this is a good quality picture.

A laboratory model was built at Bell using the actual components. No film was used. The flying spot was traversed across a razor edge to obtain verification of previous calculation.

The results were:

a. Rise time of 55 nsec under very carefully controlled conditions.

b. Rise time of 90 nanosecond under normal alignment conditions.

c. Signal to RMS noise of twenty-five to one.

4. Video Amplifier Chain - The video amplifier chain contained high frequency microcircuit amplifiers. The use of microcircuits was feasible since the main source of noise was the P.M. tube.

The final video amplifier was a purchased item and was modified by Bell. The amplifier was advertised as a 20 mc device but tests at Bell showed that the amplifier had severe time delay distortion. High frequency overshoots to transient would cause ringing on the final display.

The final rise time of the amplifier turned out to be 35 nsec with no smear or overshoot.

The block diagram of the video system contained two additional microcircuits with t_r of 15 nanoseconds each. Hence, the overall rise time of the system in lab conditions could be calculated

$$t_r = \sqrt{t_1^2 + t_2^2 + t_3^2} = \sqrt{90^2 + 35^2 + 2(15)^2} = 98 \text{ nsec.}$$

where t_1 = F.S.S. rise time out of the phosphor compensation circuits.

t_2 = video amplifier (final) rise time

t_3 = microcircuit rise time.

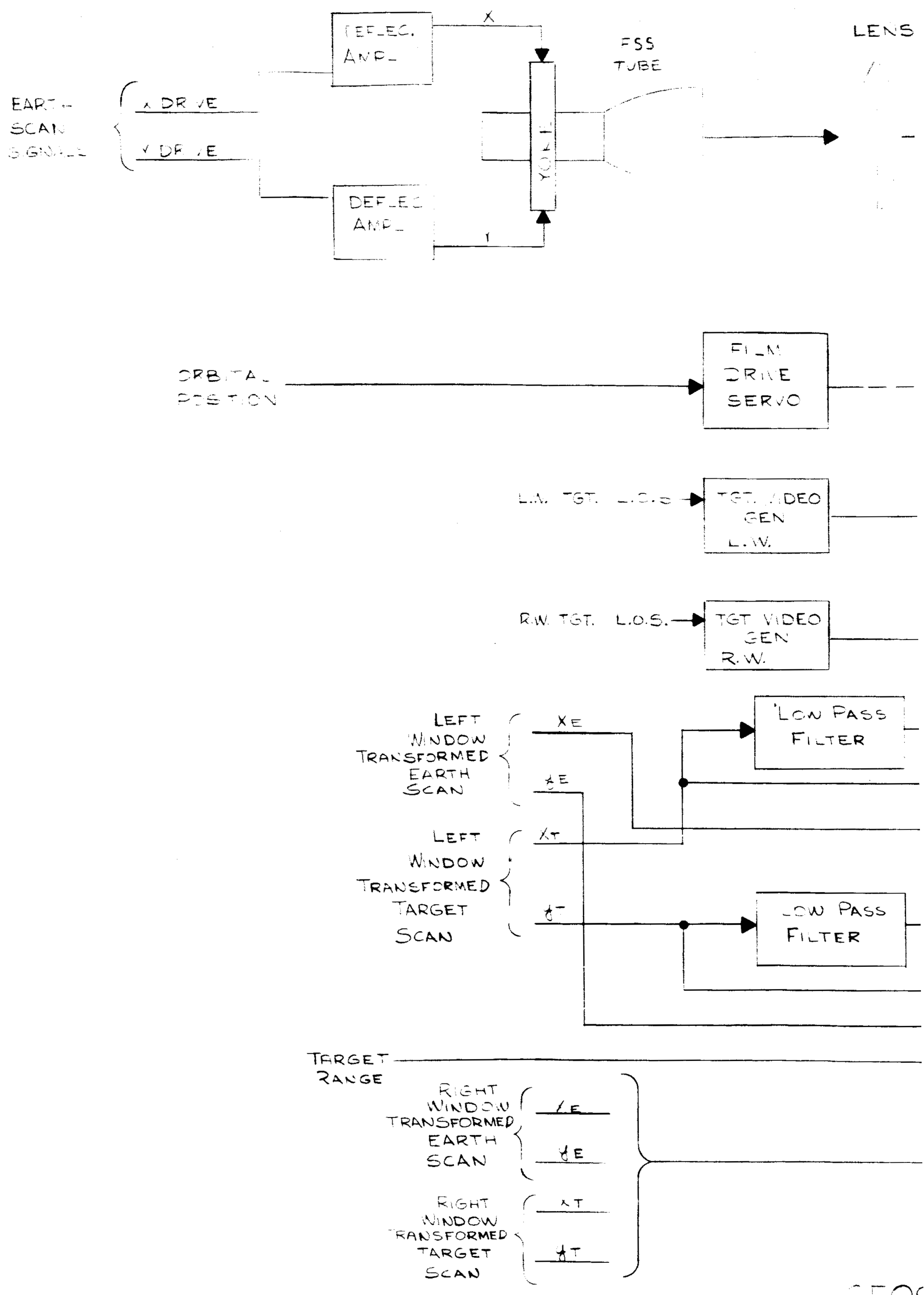
Referring to Section II.D.2 (pg18) the design goal was a rise time of 190 usec. The results above show that a capability exists that is better by a factor of two. Allowing for error caused by the assumption of that Section , the video capability is still well withing the resolution requirements.

Later in the program, the display spot velocity was increased from a nominal .75 inch/usec to a nominal 1.25 in/usec. The flying spot scanner spot velocity was lowered due to the haze reduction scaling change. The resultant resolution decrease from these two is about 100% which is still better than necessary.

Refer to the video functional diagram, Figure 8. The point of injection of the insetting occurs after the F.S.S. video channel. The rise time to the final display from this point is about 40 nsec. The quality of the insetting pattern can be estimated. Allowing for a 40 nsec time interval from full white to full black, the intensity goes thru a gray level in the transition. The apparent transition to black occurs in less than 40 nsec (about 25 nsec). In terms of visual acuity, the 25 nsec time period is about 5 minutes of arc at the originally designed spot velocity.

5. Power Supply Noise Problem - During checkout of the system, considerable trouble was encountered from the chopper type high voltage power supplies used in GEOS. The supplies radiated spikes at the chopper frequency. Heavy shielding and decoupling techniques were inadequate to suppress the noise that resulted on the photo-multiplier preamp outputs. Finally all were replaced by sine wave oscillator type supplies resulting in a complete elimination of the problem.

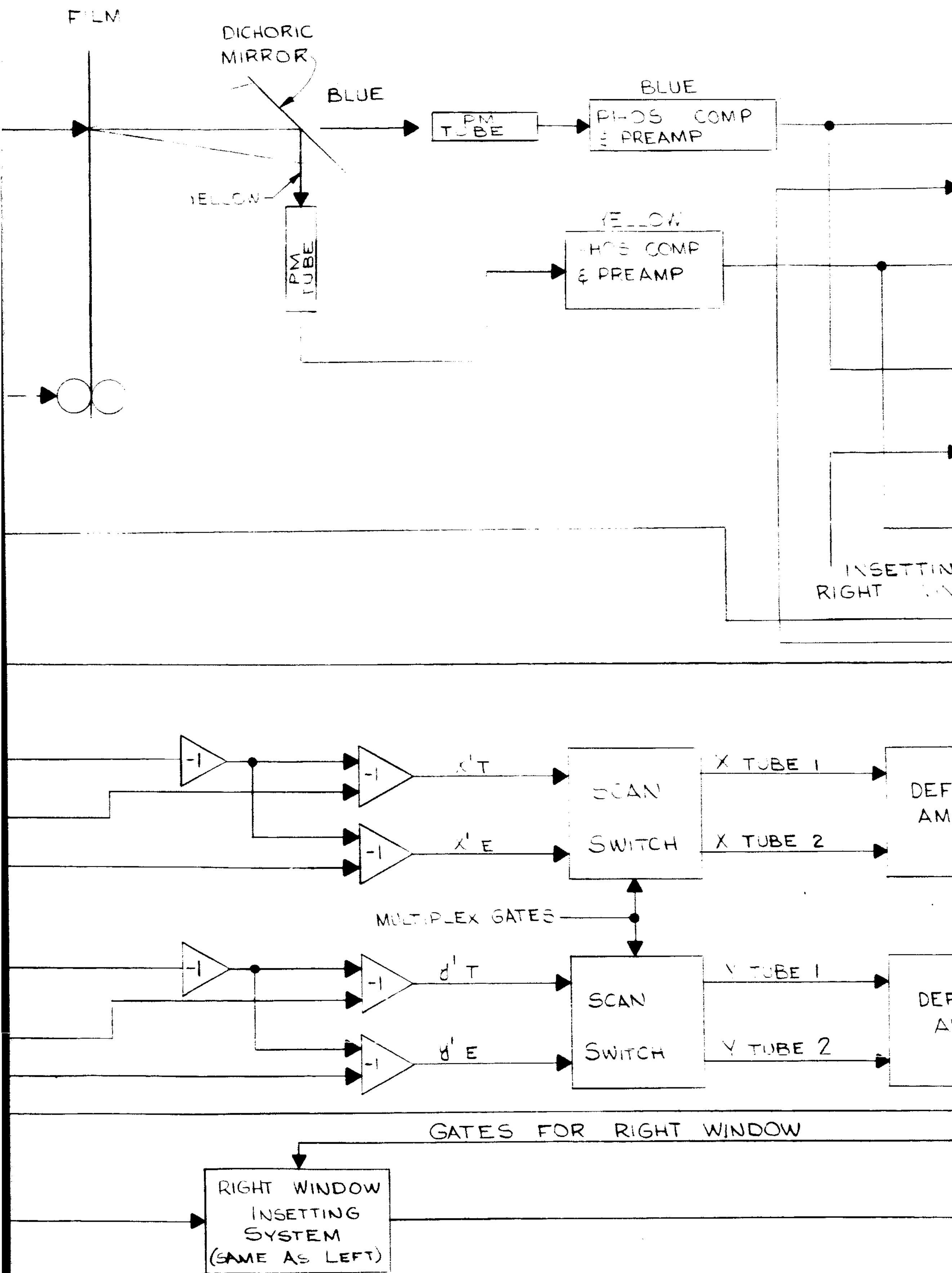
6. Horizon Haze - GEOS was designed to have earth data to within 10° of the horizon. The last 10° was an unfeatured haze. The method for accomplishing this was to let the spiral scan extend beyond the edge of the FSS CRT phosphor.



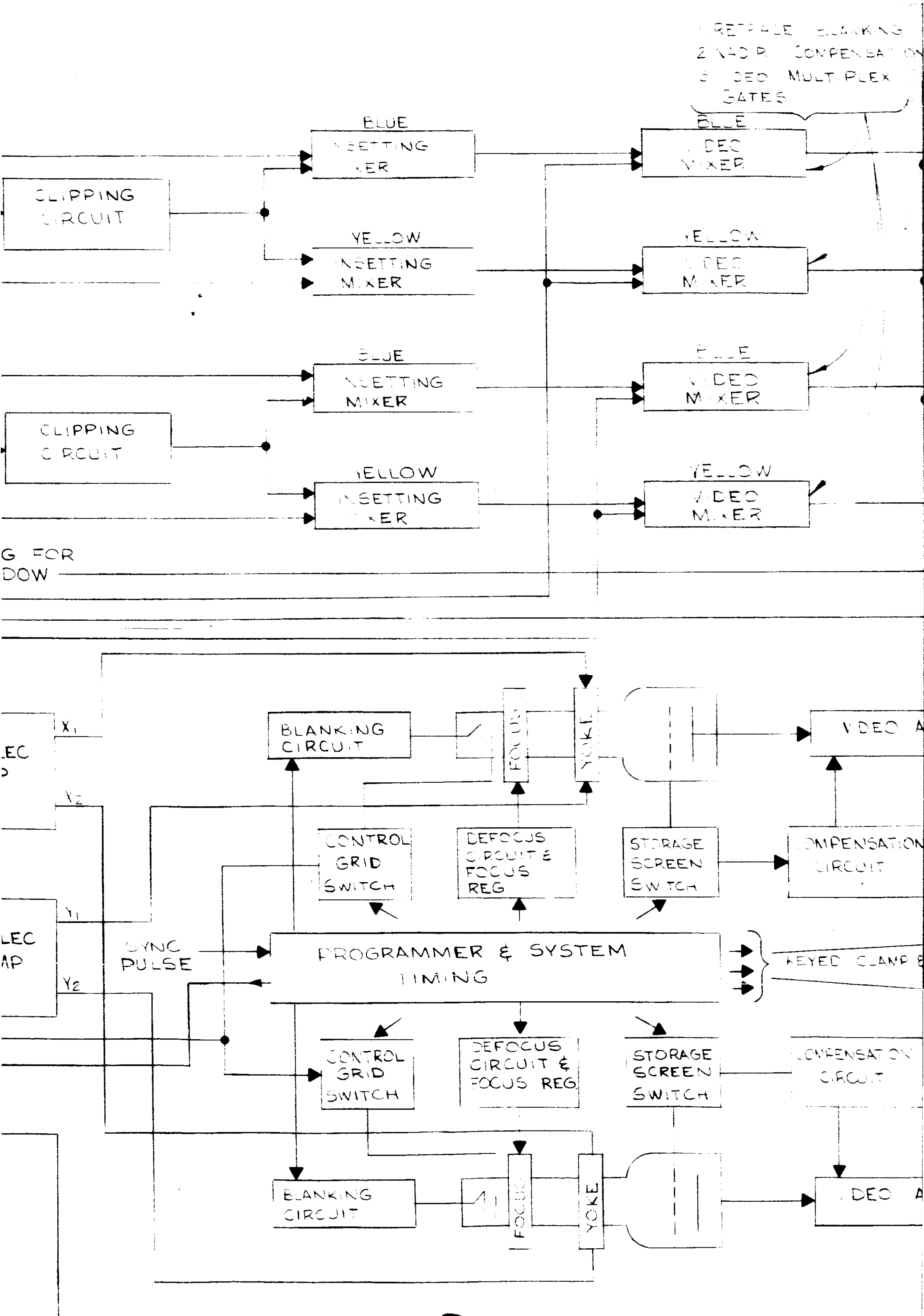
DEFLEC. AMPL.
X
FSS TUBE
LENS
EARTH SCAN SIGNALS
X DRIVE
Y DRIVE
YOKE
DEFLEC. AMPL.
Y
ORBITAL POSITION
FILM DRIVE SERVO
L.W. TGT. L.O.S.
TGT. VIDEO GEN L.W.
R.W. TGT. L.O.S.
TGT. VIDEO GEN R.W.
LEFT WINDOW TRANSFORMED EARTH SCAN
XE
YE
LOW PASS FILTER
LEFT WINDOW TRANSFORMED TARGET SCAN
XT
YT
LOW PASS FILTER
TARGET RANGE
RIGHT WINDOW TRANSFORMED EARTH SCAN
XE
YE
RIGHT WINDOW TRANSFORMED TARGET SCAN
XT
YT

GEOS

22-1



S- VIDEO SYSTEM FUNCTIONAL


GATES
BLUE
VIDEO MIXER
CLIPPING CIRCUIT
YELLOW
INSETTING MIXER
YELLOW
VIDEO MIXER
BLUE
INSETTING MIXER
BLUE
VIDEO MIXER
CLIPPING CIRCUIT
YELLOW
INSETTING MIXER
YELLOW
VIDEO MIXER
BLANKING CIRCUIT
FOCUS
YOKE
VIDEO
CONTROL GRID SWITCH
DEFOCUS CIRCUIT & FOCUS REG
STORAGE SCREEN SWITCH
CIRCUIT
SYNC PULSE
PROGRAMMER & SYSTEM TIMING
CONTROL GRID SWITCH
DEFOCUS CIRCUIT & FOCUS REG
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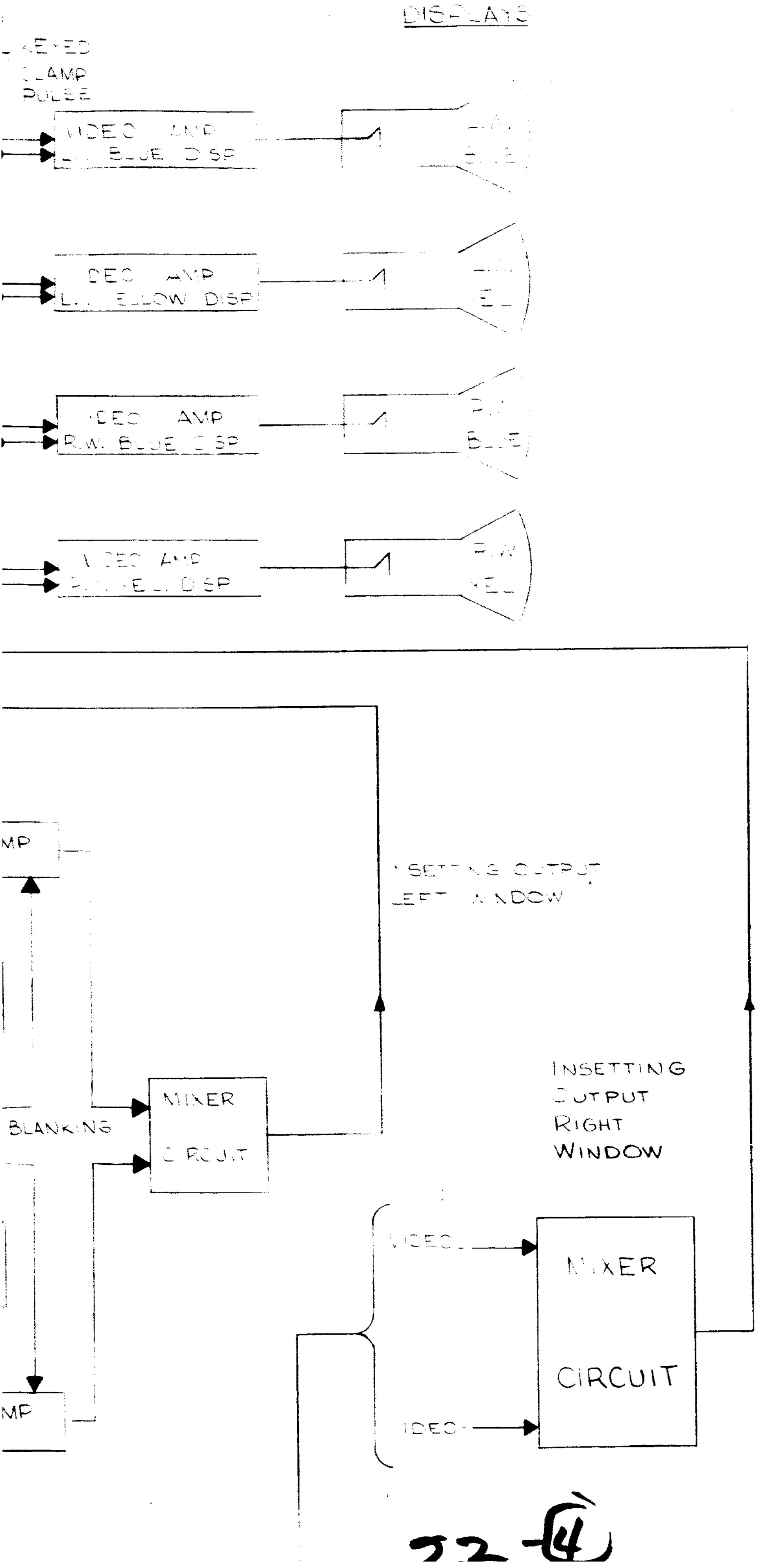
BLANKING CIRCUIT
FOCUS
YOKE


DISPLAYS
CLAMP
PULSE
AMP
AMP
AMP
R.W. BLUE DISP
AMP
BLANKING
MIXER
INSETTING
OUTPUT
RIGHT
WINDOW
MIXER
CIRCUIT

22-(4)

Since the FSS is a negative system, this haze area would then turn white. No method had been employed to adjust the intensity of this haze to match it with the data area of the picture. Also it looked unrealistic because it was too even at the transfer point between data and haze.

To correct this and provide more realism, we rescaled the FSS scan to provide data to within about 1° of the horizon at which point it became a haze. This now means that film scaling must be changed for altitude changes above 100 miles.

II. E. Displays - Display in Visual Simulation is one of the major trouble areas. The eye has such good resolution near the center of its field of view and this field can be easily directed over a wide area. Therefore, display systems need to be wide field of view with high resolution over the entire area. In addition, the GEOS system must be high brightness to make up for optical system losses, and it must be a color display.

Two inputs were available on the Infinity Optics system, so that a two color, two display arrangement was used for each Gemini window. High brightness ruled out shadow mask types of tubes. Band pass limitations ruled out color sequential systems. The system was therefore designed to have the two colors scanned onto two tubes which were then to be superimposed via a dichroic.

The scan frequencies involved appeared to force a maximum spot velocity of about 1"/usec. Registration had to be met with scans on the displays from D.C. to 100 KC.

Checkout of the system revealed several problems not anticipated. Firstly, the earth's magnetic field severely affected registration so that as position of the displays was altered, the registration was changed. This meant that the displays would have to be registered in the final system in the flight capsule position. Secondly, a calculation mistake on the effect of scan frequencies for worst case spot velocity was found. This meant that the displays should really be handling a spot velocity of 1.5"/usec. Compromises were made in checkout on the scan frequencies which were reduced by about 17%. The displays were operated at 1.25"/usec. This they could do, however, some difficulty was encountered with the limiting under these conditions. Subsequent work on the GEOS system to provide limiting prior to the display was successful in solving this problem.

Color registration has been set up by the careful addition of permanent magnets on the neck and bell of the CRT's. However, either due to the shock the displays sometimes get during movement of optical system, or due to the changing magnetic field conditions within the simulation room, the displays do not remain registered over long periods of time. We would recommend that when improvements are considered for the GEOS system, work to be done on providing new CRT displays that have electro magnetic centering and heavy shielding around the CRT similar to the new color television techniques. At the same time improved deflection amplifiers, which now exist, could be used to provide a better spot velocity margin.

F. <u>The Insetting System</u> - Insetting for one window requires two CK1500 tubes to produce a continuous insetting readout signal. While one tube reads out for two successive 16 millisecond periods, the other tube is erasing for one period and writing in new information during the next period.

Inquiries to several manufacturers revealed that no attempts had been made to date at erasing all information in one 16 millisecond period. Raytheon stated that they had a developmental tube (CK1500) which they believed capable of this requirement. A visit to Raytheon by a Bell engineer resulted in a demonstration of the CK1500's capability and also suggestions by Raytheon engineers for the best approach to design.

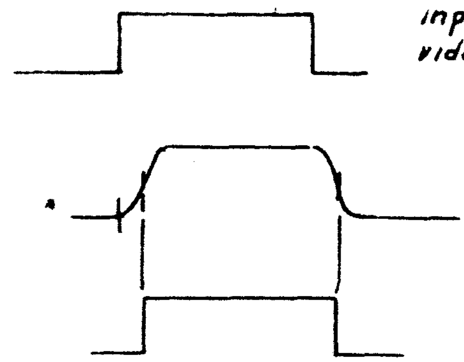
The write mode is a normal operation used to store target information on the storage screen. The read mode is another normal operation using earth scan to obtain readout except that moderate beam current is used in a partially destructive manner. The erase mode is a target scan readout mode with very heavy beam current for complete destruction of the written information.

The first requirement was the rapid updating feature of this insetting system. Elimination of the effect of the storage screen to output electrode capacitance was necessary. This capacitance couples the leading and trailing edges of a 300 volt, fast rise time storage screen pulse directly into the high gain video amplifier. The feedthru of the trailing edge overloads the amplifier and the amp does not recover in time for proper transmission of the readout signal. As many as 5 to 10 fields may be required for recovery.

The solution to this problem was the design of a special storage screen pulse circuit to minimize feedthru; also a compensation circuit was designed to counteract whatever feedthru occurred. The compensation circuit is part of the input circuitry of the video amp. Thus the video amp is never overloaded and rapid updating is possible.

The second requirement was adequate resolution of the insetting signal at the point of injection into the earth video channel. This is accomplished by applying the 500 mv insetting signal with rise time of 100 nanosecond (this is 0.2 nanosecond per mv), to a microcircuit zero crossing detector with a full output capability of 15 nanosecond with 15 mv input (this is 1 nanosecond per mv at input) since the input signal goes thru 15 mv in 3 nsec, then the microcircuit operates at its full capability and produces an output pulse with a rise time of 15 nsec. This is injected into the earth video channel and transmitted in the video chain to the display CRT's. Refer to GEOS video bandpass design approach on page 17.

If the microcircuit triggers near the 50% point of its input signal no signal stretching occurs but only signal delay. Refer to Figure 9.



INSETTING SIGNAL DELAY

Figure 9

With an insetting output of 100 nsec rise, the delay is 50 nsec. At 1.2"/usec spot velocity on the final display, the original design objective was that the insetting error would be under 4 lines. Since the decrease in apparent resolution, this error is now under 2 lines.

To assure a 100 nsec rise time signal into to microcircuit, a calculation was made based on Raytheon's tube capability. A resolution of 1000 TV lines at 50% amplitude across the storage screen diameter was quoted as resolution specification. Assuming the use of 75% of the storage screen diameter to equal 90° field of view, then 750 lines are achievable in 90° field of view. At 1.2" per usec on final display, 750 lines (corresponding to 375 cycles of information) results in 42 nsec per cycle. Considering sine wave response only, the insetting signal can rise to 50% in 21 nsec. Since this output is 250 mv and still in excess of the microcircuit input requirements, the tube itself is fully capable of the resolution requirements.

The video amplifier was designed for 45 nsec rise time and tested to this spec. Thus, the input to the microcircuit is $\sqrt{t_1^2+t_2^2} = \sqrt{21^2+45^2} \approx$ 50 nsec. A safety factor of two is used in the assumption of 100 usec signal risetime into the microcircuit.

Observation of the insetting hole on the earth data in the final display showed a well-defined, sharp insetting pattern indicative of high resolution.

III. SUMMARY OF RESULTS

In general, the GEOS system promises to be a usable technique for earth orbital scene generation. Some areas of this prototype design have been proven to be entirely satisfactory, while other areas show need of improvement.

The major problem affecting the quality of the display is the electrical and magnetic noise of the GMS environment. Input D.C. voltage from the driving computer have at times been 1.5V peak to peak noise on 10V D.C. signals. We have filtered to substantially reduce the effect of this type of noise, but more work needs to be done to reduce the noise at its source. High frequency digital computer noise is apparently being radiated and picked up on some transmission lines within the GEOS system. Since variable frequency scan is used in GEOS, this noise cannot be easily filtered.

The second major problem affecting image quality is apparent resolution reduction due to the difference in brightness of the two colors used for the displays and due to the particular scan that was used. Referring back to II. A. of this report, note that the whole earth cap is scanned rather than a portion ahead of the Gemini Spacecraft. The resolution loss due to this is about 15%. These two losses put together means that we are getting an apparent resolution of only 42% of that originally intended.

Other areas needing improvement are as follows:

a. Color registration can be set to less than .5% of deflection distance as intended but doesn't stay registered this well. Careful testing on this system during use would have to be done to establish the deviation and the reasons for the change.

b. Scan from nadir to horizon with variable frequency has resulted in no phase or sync sense on the horizon scan line. The result is that this last scan line sometimes pulses. Changes have been made in the system to compress the last several scan lines to reduce this effect, however, in the future, it would probably be better to scan in the reverse direction; that is, from horizon to nadir.

c. The haze method for the last 10° of horizon looked unrealistic, therefore, changes in scaling were made to extend earth data to within about 1 degree of the horizon. This was done by setting the FSS optical system in the 300 mile condition and readjusting the scan amplitude to just cover the film.

d. The color flying spot scanner has, in general, worked very well. We have obtained the desired bandpass without objectionable video noise. Future work could possibly be done to improve the color balance through additional special tailoring of the negative color film. High light brightness of 200 ft lambers has been achieved.

e. Display spot sizes of 15 mils at the CRT center has been obtained. Spot size was checked on the displays before incorporation into the system.

f. The earth defocusing system has also been shown to be workable. As target range is reduced, the earth is defocused according to a 1/R function, which gives the desired impression that the target is nearer than the earth.

g. System static accuracy was to be $\pm 3°$. Actually the target portion of the system has been aligned to about $\pm 1\%$.

IV. MODIFICATION RECOMMENDATIONS

Recommendations for the future of the GEOS type system must be handled differently depending upon whether the existent system is to be improved or whether a new system is to be built.

Firstly, we will consider modification to the existent device to improve performance and to provide a wider flexibility.

1. Increase resolution by the following:
   a. Work on noise problem in GMS facility.
   b. Revise raster generator and order of transformation to provide spacecraft stabilized scan.
   c. Incorporate variable time sharing between target and earth.

   The total increase in earth resolution will be almost 100%. The increase in target resolution will be 33%.
2. Change raster generator to give horizon to nadir scan.
3. Change film drive system to take up reels providing 20 orbits and providing a fast bi-directional reset.
4. Change multiplexing scheme so that the same information is put on both displays at once; that is, Blue Earth and Yellow Earth at one time, and Blue and Yellow targets at one time. This will tend to reduce the effect of noise on the system.

V. RECOMMENDATION FOR BUILDING A COMPLETE NEW UNIT

There are many improvements that could be incorporated into a new GEOS type system. We have learned the things stated in previous sections of this report, but also we have learned relative worth of the various portions of the system. Also we now know of system and packaging changes that will reduce the susceptibility to external noise.

In addition, there are display improvements that can be made. In general, we believe that the next system can be a tremendously improved version of the prototype.

A. Noise - One of the disadvantages of electronic image generation compared to closed circuit television is that the display does not contain the raster generator as in television. Therefore, long transmission lines carrying scan signals are potential noise sources.

In television, the tuned raster is generated within the display and only sync pulses are transmitted to this display. The result is nice clear scan lines.

In GEOS, this could be done by placing the raster generator, the coordinate transformation, and the display multiplexing cards in a unit adjacent to the displays. The raster generator and multiplexers for earth signal consists of about 30 cards. These with the servos could be quite easily packaged in a unit 15" high x 19" wide x 25" deep. If the target scan generator with its servos were added, the package would have to be 20" high.

With more work done on packaging, this space could be cut even more making the auxiliary unit about the size of a large display power supply. It could be mounted right on the Farrand display system. We have had good success with clear scan signals when short transmission lines have been used.

B. <u>Insetting</u> - The relative value of insetting seems low when compared to the cost and reliability effect on the total system.

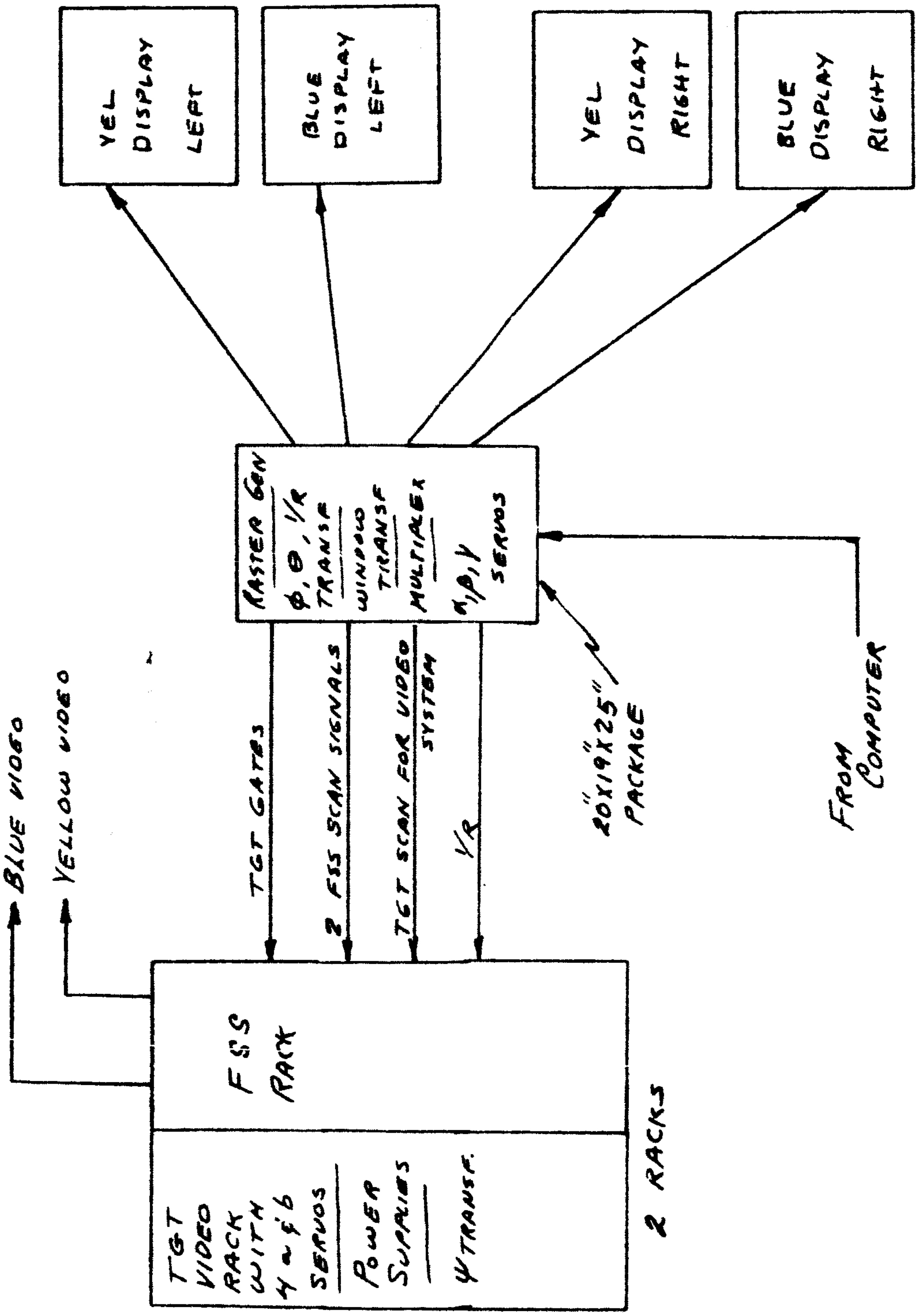
The original Agena target generator was a completely solid state device, except for the display. GEOS, on the other hand, has 4 CK1500 storage tubes in the insetting system with their associated 8 deflection amplifiers, 4 video amplifiers, and other switching circuitry. Also it has a flying spot scanner tube with 2 deflection amps and 4 display tubes with 8 deflection amplifiers. The reliability of the system is considerably decreased by this collection of nine CRT's with their deflection systems, high voltage and focus circuits.

Usage of the GEOS system without insetting has been entirely adequate. The bleed through of earth and stars into the target image does not appear objectionable. If the proposed variable time sharing feature were incorporated, the earth would be greatly defocused whenever the target image is close (large). Bleed through of features is thereby even reduced further.

We would recommend that a future GEOS system not include insetting.

C. All of the changes that are listed in Section IV should also be incorporated in a new system.

The resultant system would probably be packaged as shown in Figure 10



NEW GEOS LAYOUT

FIGURE 10