III. The Electronics of the KAPPA Rocket

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1. Introduction

When work on a sounding rocket began in 1955, the objective to be attained in the field of electronics was the perfection as a system of telemeter and tracking equipment for a sounding rocket slated to be launched (to an altitude of 80-100 km) during the International Geophysical Year (1957-1958). Since then over five years have passed, and although many difficulties were encountered in rocket development during that time, they are now in the process of being overcome, and we have progressed to the KAPPA-8. The next objectives for development are the KAPPA-9 and 10, which are expected to be realized in the not-too-distant future.

Since the altitude goal of the IGY was from 80 to 100 kms, all electronic equipment was designed to function at a communication range of 150 km. The equipment was continually improved until it reached its present state. As the maximum altitude of the rockets increased considerably, the range also increased markedly, and finally the electronic equipment reached the limit of its capability. Plans are now under way to improve the performance of the electronic equipment further from 1960 on, and the manufacture of new, more accurate equipment is now in progress. In this sense the electronic equipment is on the verge of a new stage of development. For reference, the nature of present equipment and the goals in the development of new equipment are described below.

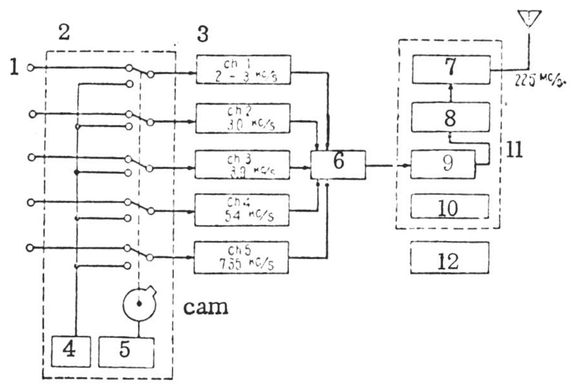
2. Telemeter System

(1) Structure of the System

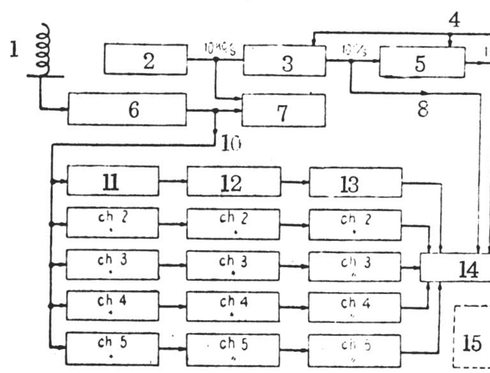
The telemeter system is composed of a rocket-borne telemeter transmitter and a ground recording and receiving installation for receiving and recording the transmitted signals. A block diagram of the system is shown in Figure 1. It is a 225 Mc/s FM-FM system with 5 channels (the number of measured quantities which can be transmitted simultaneously). In the FM-FM system, variations in measured quantities are converted into frequency variations by oscillators (called subcarrier oscillators) which convert changes in measured quantities into changes in frequency. The primary carrier wave (in this case 225 mc/s) is frequency modulated and transmitted. The system allows simultaneous transmissions of various information by a single transmitter. The ground receiver separates the information into the respective components through band-pass filters.

(2) Telemeter Transmitter

(a) Structure. In the subcarrier oscillator, the frequency varies in proportion to the center frequency within a range of ±7.5% depending on the measured signal voltage of 0 to 5 volts. As shown in Figure 1, the center frequencies are 2-3, 3.0, 3.9, 5.4, and 7.35 Kc/s. The signal input terminal impedance of the subcarrier oscillator is 500 kΩ. Consequently, the measuring instruments in each case must be designed so that for a load of 500 kΩ, the range of variation provides a signal voltage of



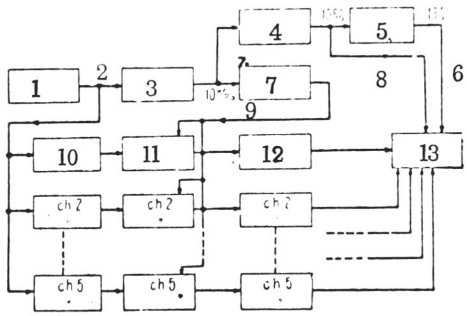
(a) Telemeter transmitter.



(b) Telemeter receiver-recorder (during flight).

Legend:
1. signal input 0 to plus 5V
2. automatic calibrator
3. subcarrier oscillator
4. standard voltage
5. micromotor
6. mixer
7. power amplifier
8. 225 Mc/s primary oscillator
9. modulator
10. A-power source
11. airtight container
12. B-power source

Legend:
1. receiver antenna
2. 10 kc/s crystal oscillator
3. decatron counter, 3 stage
4. launching signal
5. decatron counter, 1 stage
6. 225 Mc/s FM receiver
7. tape recorder
8. 0.1 sec. signal
9. 1 sec. signal
10. 5 channel subcarrier oscillator mixed signals
11. Ch. 1 band pass filter
12. Ch. 1 frequency discriminator
13. Ch. 1 DC amplifier
14. pen oscillograph
15. magnetic oscillograph



(c) System diagram for regenerated recording.

Legend:
1. tape recorder
2. regenerated signal
3. 10 kc/s (band pass) filter
4. decatron counter, 3 stage
5. decatron counter, 1 stage
6. 1 second signal
7. 10 kc/s frequency discriminator
8. 0.1 second signal
9. compensating signal for loss in velocity
10. Ch. 1 band pass filter
11. Ch. 1 frequency discriminator
12. Ch. 1 DC amplifier
13. pen oscillograph

Figure 1. System Diagram of Telemeter Apparatus

0 to + 5 V. By unifying the standards of the measurement signals it becomes possible to discriminate clearly between the measuring instruments and the telemeter transmitter, and operations can be carried out smoothly. The 5 subcarrier signals are applied equally, enter the modulator, and the 225 mc/s primary oscillator is frequently modulated. The output of the primary oscillator is amplified and passed to the transmitting antenna. The transmitted output is approximately 1-watt. The maximum frequency deviation of the 225 Mc/s modulation is ± 100 Kc/s. The frequency of the secondary carrier wave oscillator (which converts the measured quantities into frequency variations) must be sufficiently stable, in relation to changes in power voltage and other environmental conditions, or errors will occur. For this purpose, the circuit construction and parts used have been sufficiently studied, and an in-flight calibrator has been constructed for the purpose of increasing the data reliability. This causes the micro-switch to move by means of the cam of the micromotor drive, and switches over the signal input terminal to a standard voltage. As shown in Figure 2 the calibration signals are inserted in various places. Since data is lost

for 0.2 to 0.3 seconds when one calibration signal is made, it cannot be used when the measured quantity shows any violent or sudden changes. In the present system, for two channels, three calibration signals and fo three channels two calibration signals can be applied to each.

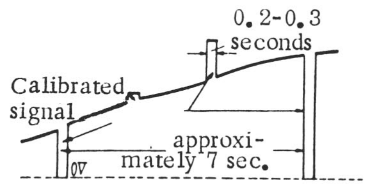


Figure 2. Operation of automatic calibrator.

(b) Power Source. The present telemeter transmitter is a vacuun tube system, using a total of 19 tubes. All of them are subminiature. Heater power required is 6.3-volts, 4-amperes and B-plus power required is 160-volts, 90 milliamperes. The battery for power source A i an imported American Yardney silver oxide alkaline storage battery (trade mark Silvercel) HR-3 (nominal capacity 3 AH). When 5 of these are connected in series, the terminal voltage for a 4 A discharge is abou 7 V and can be used continuously for 40 minutes.

The Silvercel, built for use in rockets, is extremely small and light, and resists acceleration and vibration. Moreover, if turned upside down the electrolyte will not leak out and is ideal since the terminal voltage remains almost constant during discharge. The volume of one HR-3 including the terminal is 15 x 44 x 73 mm and its weight is 80 gr. Its external view is as shown in Figure 3.

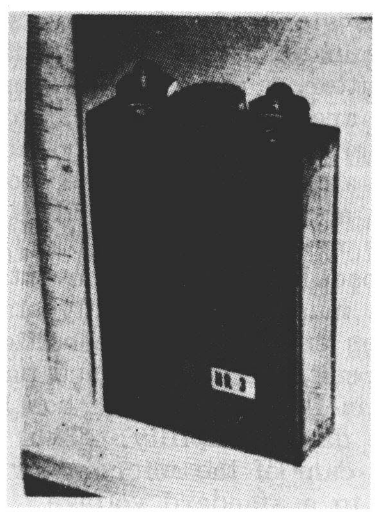


Figure 3. Yardney Silver Cell.

The battery for B^+ voltage is a silver chloride layer built cell developed by Yuasa Batteries. In this battery, as discharge progresses, the silver chloride is reduced to silver. Since the internal resistance is low, the terminal voltage during discharge is very steady. This supplies the required power for 30 minutes. Its weight is 500 grams. Although the unit rate and the volume capacity is quite excellent, one defect is that its preservability is poor.

A method for supplying the B^+ voltage is a system which separately changes the low voltage power source (power source A) into AC, and boosts and rectifies it by means of a transformer. Figure 4 is a DC-DC

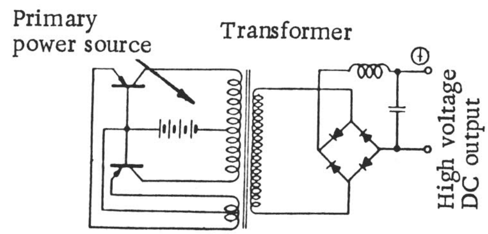
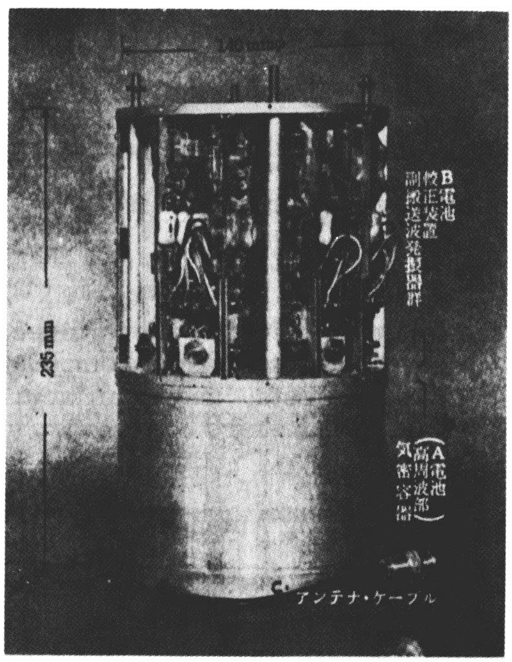


Figure 4. Transistor DC-DC converter.



a-Battery, calibrator, group of sub-carrier oscillators; b- (A-battery high frequency section), airtight container; c-Antenna cable.

Figure 5. Construction of telemeter transmitter.

converter using transistors for switching elements. When the primary voltage reaches 6 volts, it is difficult to realize any high efficiency but nevertheless it is about 70%. That which was designed for use in the above-mentioned power source B has about the same weight and volume as the silver oxide dry cell, but there is no need to be concerned about its preservability or manufacturing defects.

(c) Construction. Figure 5 shows the construction of the telemeter transmitter. It is a cylinder 35 mm high with a diameter 140 mm for the 150 type rocket. Its weight without the power source is 1.8 kg. Due to low pressure in the upper atmosphere there is a danger that the radio frequency produced with a high operating voltage will cause an electrical discharge, and since battery A is agitated by the electrolyte these are put into an airtight container. Everything was made airtight in order to reduce weight. Figure 6 shows the inside of the airtight container.

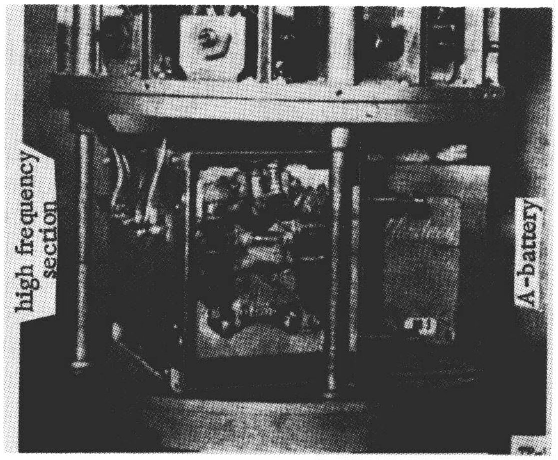


Figure 6. Internal construction of airtight container.

The tubes and other circuit elements were directly installed on printed wiring boards hardened with an elastic compound. Judging from the results of shock and vibration tests, and from actual performance in many experiments, we may say that there are no problems in regard to strength.

(3) Telemeter Transmitting Antenna

The antenna efficiency must be essentially constant during flight. Also, it must be sturdy and non-sensitive to heat. The directivity must be as broad as possible in order to receive adequately even during changes in direction and attitude during flight. The telemeter transmitting antenna now in use has the construction shown in Figure 7. Although this is the one used in the KAPPA 6, it is also used in other rockets in the same form with only the dimensions changed. Taking advantage of the sandwich construction of the tail, a cable was passed between the front of the conductor and was led from the trailing edge of the tail towards the rear. Radiation takes place behind the rocket. The cable goes along the outside of the engine section, and is led as far as the telemeter transmitter section. The cable is of heat resistant teflon and is protected against the heat by teflon tape and glass wool. Copper plated piano wire is used to increase the mechanical strength of the conductor.

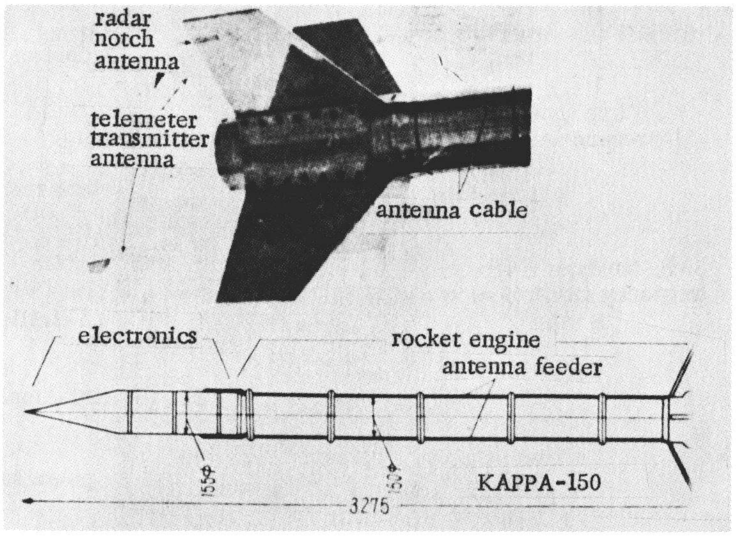


Figure 7. Telemeter Transmitter Antenna (KAPPA-6 main rocket).

In the KAPPA 6, the cable is bound with piano wire affixed to the engine section, and coated with heat resistant paint. In the KAPPA-8 the conductor cable is led through steel pipe, attached in the same way to the engine, coated with heat resistant paint, and devised so that its resistance to heat is even greater.

(4) Receiver, Recorder System

(a) System. A block diagram of the receiver-recorder system is as shown in Figure 1. The 225/Mc/s FM signals received by the antenna are demodulated by the receiver and the mixed outputs of the subcarrier signals of the 5 channels are obtained. These are divided into their respective components by a group of band pass filters, the variations in frequency are converted to variations in voltage by a frequency discriminator, amplified into AC and recorded by a pen or oscillograph. The signal frequency components of the measured quantities can be transmitted up to 150c/s. However, a signal containing such high frequency components does not respond to the pen or oscillograph, so a magnetic oscillograph is used. Separately, time signals of 0.1 seconds and 1 second are made through a decatron counter circuit from a 10Kc/s crystal oscillator and by this the time is adjusted. The time signal is made to begin generating at the moment that the launching switch is thrown on, and the time axis origin is determined by this.

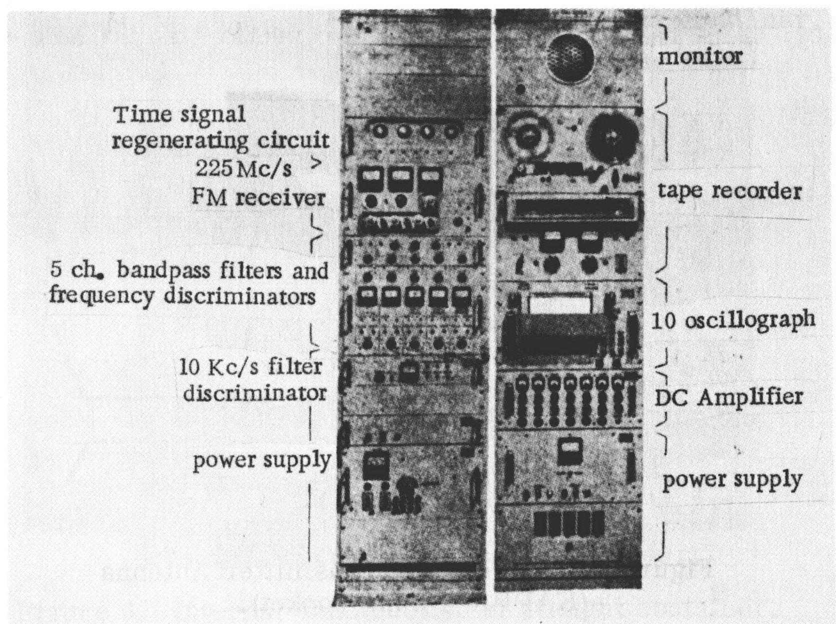


Figure 8. Telemeter receiver recorder equipment.

The receiver outputs, i.e., the subcarrier mixed signals are recorded separately on tapes. If the ink for the pen or oscillograph should run out, if the photographic equipment fails in the magnetic oscillograph, or if direct recording fails during reception as a result of irregular damage, it is still possible to correct the recordings by regenerating the contents of the tape (see Figure 1). In this case, since there is a fluctuation in the frequency of the regenerated output due to changes in the speed of tape, wow or flutter errors are mixed in the recording. In order to prevent this, the 10Kc/s crystal oscillator output, as a standard frequency a the time of recording, is also recorded beforehand. When regenerating, this 10Kc/s component is separated and the fluctuation in frequency due to fluctuation in tape speed is detected by a highly sensitive frequency discriminator. By its output, the errors generated in the separate outputs of each channel are automatically compensated for.

(b) Receiver Antenna. The transmitter antenna shown in Figure 7 is a linear polarized wave within a surface containing the tail on which it is mounted. When the rocket spins the planes of the polarized waves rotate at the same time and when the receiver antenna is the same linear polarized wave, both planes of the polarized waves cross at right angles (twice in one spin) and reception is absolutely impossible. In order to avoid the inconvenience accompanying the rocket spin, it is a good idea to use an elliptical polarized wave form for the receiver antenna. Figure 9 is a photograph of one such antenna, called a helical type which is presently in use. It is possible to control the direction of the antenna manually,

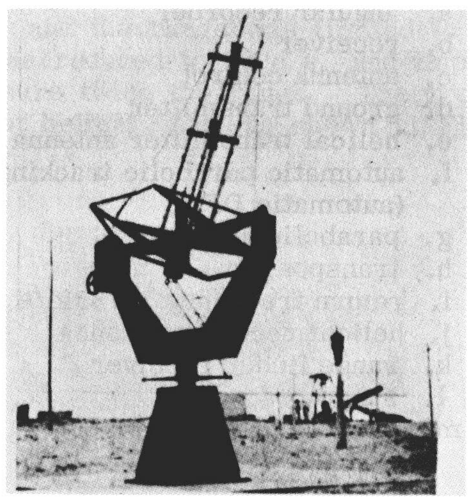


Figure 9. Helical antenna for telemeter receiver.

and it is adjusted to the direction of the rocket during the rocket flight. However, since the directivity is not very accurate (half value width 50°) it is usually sufficient to align it with the general direction.

3. Radar Installation

(1) System

There are several systems for tracking the positions of a rocket at every moment by using radio waves. The system used for the KAPPA rockets at the present time is shown in the system diagram in Figure 10.

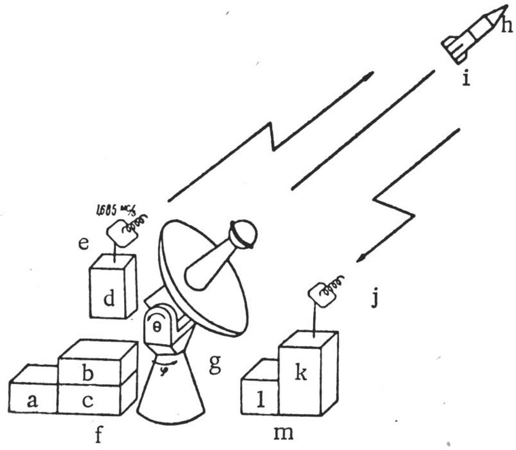


Figure 10. System diagram of radar equipment.

Legend:
a. angular recorder
b. receiver
c. antenna control
d. ground transmitter
e. helical transmitter antenna
f. automatic parabolic tracking antenna (automatic DF)
g. parabolic antenna
h. transponder
i. return frequency 1675Mc/s
j. helical receiver antenna
k. range finder receiver
l. range recorder
m. range finding equipment

in this system the direction and distance of the rocket are measured from one point and position is found. The ordinary radar system finds the direct distance from the time taken for a pulse radio wave to be transmitted from the earth and reflected back from the target. This is the so-called primary system. In the case of KAPPA rockets, however, since the effective reflecting surface is small, an extremely large ground installation would be needed in order to plot over great distances. Therefore, a secondary radar system is used in the KAPPA rocket which carries a transponder. A transponder is a device that receives a pulse wave from the ground and immediately sends back a return signal, thus performing exactly the same functions as a reflector. Since we can design a suitable power system, it is possible to plot long distances from a comparatively small ground installation.

Direction is measured by employing the acute directivity of a parabolic antenna which operates by measuring the incoming direction of the return signal waves from the transponder. The parabolic antenna is an automatic tracking type driven by a servomechanism so that its axis coincides with the direction of the incoming radio waves. The direct range is measured by the time it takes a pulse transmitted from the ground to be echoed back from the transponder and again received on the ground by a range finder.

(2) Ground Transmitter

The transmitter frequency is 1,685Mc/s, the pulse width is 1 μ s, the peak transmitting power is 10kw and repeater frequency is 250c/s. The time that it takes for the pulse transmitted from the ground to pass through the transponder and again reach the ground as a rule must be less than 1 cycle of the repeater frequency. Up to the KAPPA-6 the repeater frequency was 500c/s, and this was effective up to 300 km (actually, in order to improve the accuracy of range finding, various precision work was done, and the range was limited to 200 km). Therefore, in the KAPPA-8, it was reduced to 250c/s, and improved so that it became possible to measure twice the range. The ground transmitting antenna is a four element helical type, as shown in Figure 11. The reason

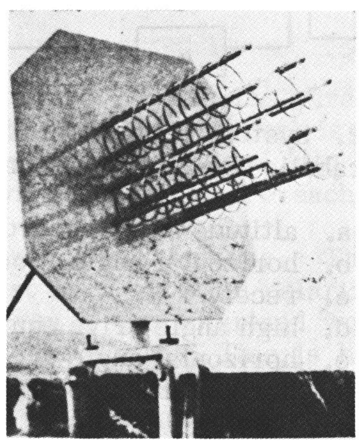


Figure 11

for using a helical antenna is the same as mentioned for the telemeter receiver antenna, i.e., since the transponder antenna attached to the rocket is a direct polarized wave type, it must be protected from being unable to receive on account of spin. Since the four elements have extremely acute directivity, it is possible to concentrate and transmit four times as much power as the single element. Since the range of the KAPPA-8 was extended, it was improved so that the transponder would receive the transmitted ground signal, while all rockets up to the KAPPA-6 were single element types.

(3) The Automatic Parabolic Tracking Antenna

(a) System. The system diagram is shown in Figure 12. A conical scanning system is used in order to detect the deviation of the antenna axis and the incoming direction of the radio waves. The principle of the conical scanner is indicated in Figure 13. When a hemispherical reflector is moved and positioned off-center in respect to an antenna placed at the focus of a parabola, the directivity of the maximum sensitivity direction deviates as shown in the illustration in respect to the parabola axis. Then if the hemisphere is rotated around the parabola axis, as this occurs, the maximum sensitivity direction of the directivity rotates conically around the center axis.

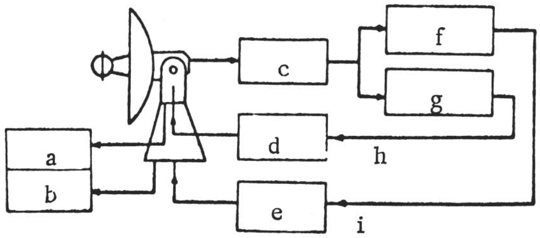


Figure 12. System Diagram of Automatic Parabolic Tracking Antenna.

Legend:
a. altitude angle recorder
b. horizontal angle recorder
c. receiver
d. high angle drive equipment
e. horizontal angle drive
f. horizontal angle error detector
g. high angle error detector
h. high angle error signal
i. horizontal angle error signal

If the incoming direction of the radio waves is in the center axis the sensitivity in respect to the rotation of the hemisphere is invariable, and the received signal strength is maintained constant. When there is a deviation in direction, since the sensitivity fluctuates periodically because of the hemisphere, there is a pulsation of the signal strength. This pulsation is detected, analyzed into a horizontal angle and high angle component, and a servo-mechanism is driven to correct the vertical and high

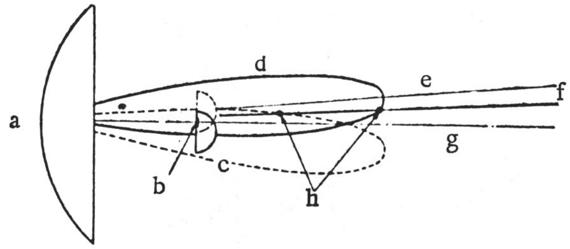


Figure 13. Detection of Angular non-error by conical scan.

Legend:
- a. parabolic reflector
- b. antenna
- c. hemispherical reflector
- d. directivity
- e. maximum directivity-sensitivity
- f. penetrating direction of radio waves
- g. center axis
- h. variations in sensitivity occur due to the rotation of hemispheric reflector

angles and reduce them to zero. Since the parabola axis (or, more accurately the center axis of the conical scanner) is directed towards the incoming radio wave, its direction is divided into a high and vertical angle and transmitted to a selsyn recorder where each instant of variation is recorded.

(b) Circular Polarized Wave Antenna. The antenna placed at the focus of the parabola, must be a circular polarized wave type which is not affected by spin. Also, even if the polarized wave surface changes, it must not be influenced by directivity. This is because when there is influence from the directivity, the direction of the center axis of the conical scanner will move and as a result an error will arise in the measurement of direction. It is known that a helical type which has a deep axis direction is suitable for the above purpose.

The circular polarized wave antenna in use at present is as shown in Figure 14. It was developed for the purpose of eliminating the above defects. Basically, it is an orthogonal dipole turnstile antenna. By suitably adjusting the lengths of the 2 dipoles which are attached to the same feed point, and adjusting the phase difference of the respective exciter currents 90°, a good circular polarized wave characteristic is realized. Details on this antenna are to be published later in this magazine. All told, satisfactory results have been obtained by using this antenna.

(c) Performance. The diameter of the parabolic antenna is 2,130 mm, depth 340 mm, and has the construction shown in Figure 15. The

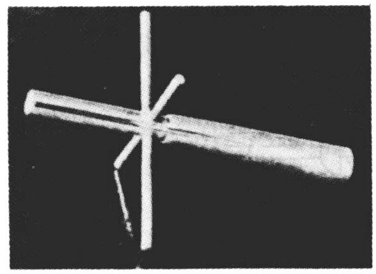


Figure 14. New circular polarized wave antenna.

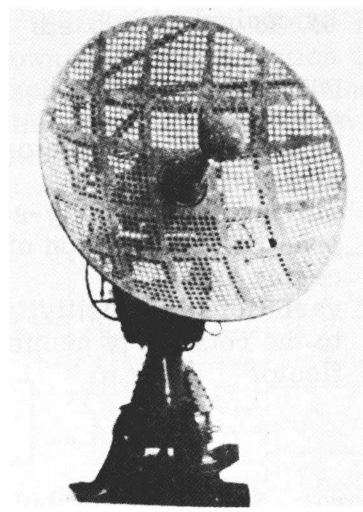


Figure 15. Automatic parabolic tracking antenna.

inclination in respect to the center axis of the maximum sensitivity direction due to conical scanning is $\pm 2°$ and scans at a rate of 25 times a second. The servomechanism is adjusted so that it tracks and lags less than 2° when the moving targets angular velocity is 2°/sec. The maximum possible angular velocity of the tracker is 6°/sec. The play and backlash of the mechanical axis is less than 0.05°.

(4) Range Finder System

(a) System. A system diagram of the apparatus is given below in Figure 16. The range finder standard is an accurate 15Kc/s crystal oscillator having a degree of stability of 10^{-6}. The ground transmitter pulse repeater frequency is formed by dividing this 15Kc/s frequency. One 15Kc/s cycle is the time required for a radio wave to propagate over 20km. Consequently, if the return signal pulse appears on the cathode

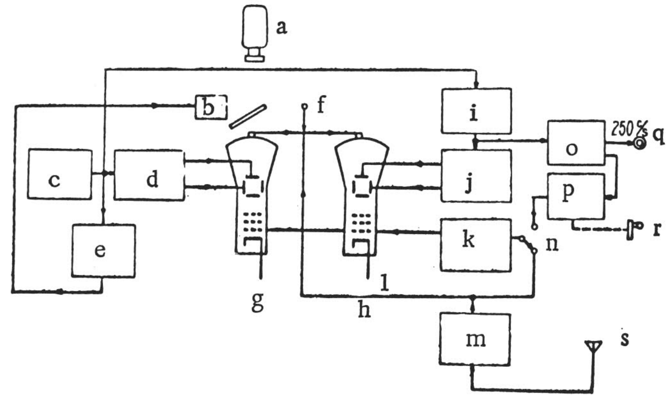


Figure 16. System diagram of range finder.

Legend:

a. 8 mm movie camera recorder
b. decatron
c. 15kc/s crystal oscillator
d. 15kc/s circular sweep signal generator
e. time signal generator
f. transmitted pulse
g. fine (20 km) J-scope
h. coarse (200 km) J-scope
i. frequency divider 1/10
j. 1.5kc/s circular sweep signal generator
k. intensity modulation signal generating circuit
l. return signal pulse
m. range finder receiver
n. manual automatic
o. frequency divider 1/6
p. delayed trigger generating circuit
q. to transmitter
r. manual operation
s. range finder receiver antenna

ray tube of the 15Kc/s circular sweep L-scope, this means that for each one cycle there is a difference of 10km in direction range (consequently a round trip of 20km). Separately, a circular sweeping J-scope cathode ray tube is inserted which makes a sweep at 1.5Kc/s which is 1/10 of the 15Kc/s and by this the variation of 200 km per one cycle (direct range 100 km) is indicated. A picture of both of these is shown in Figure 17, and by these it is possible to know the range. When the range to the rocket exceeds 100 km, the indicator of the coarse scale makes a complete revolution and returns to the 0 position. Since the time-distance relationship is already known, there is no chance of making an incorrect reading. Up to a direct distance of 400 km, the coarse scale makes 4 revolutions, the fine scale 40, and the return signal pulse is estimated by the circular sweep. Of course, the circular sweep phase is regulated so that the ground transmission pulse comes to the standard position of scale 0, and the range is immediately found by the position scale of return signal pulse.

For recording, the image of the J-scope is photographed by an

8 mm movie camera. Since the presentation si small, only the fine scale J-scope is fully copies in order to simplify the reading. If the number of revolutions is followed, there is no danger of incorrect readings. The crankspeed is 10 comas per second.

Separately, the time signal produced from 15 Kc/s is applied to a decatron, the movements of the bright points are photographed simultaneously in the center of the presentation by the construction shown in Figure 18, and the time axis is regulated. The time signal is made to generate as the switch for firing the rocket is turned on. The determination of point of origin is the same as in the case of the telemeter apparatus.

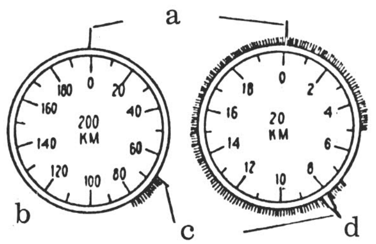


Figure 17. Indicators for range finding equipment. a-transmitted pulse (standard position); b-coarse J-scope; c-return signal pulse; d-fine J-scope.

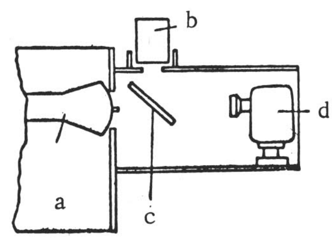


Fig. 18. a) fine J-scope, b) decatron, c) glass, d) 8mm camera.

(b) Capability. The fine J-scope is 3 inches, the scale is in 1 km (corrected to direct range-500 km), the reading accuracy is 200 m (at direct range-100 m), the maximum indicator range is approximately 400 km. In order to make the image easily readable the 18 km section in the vicinity of the return signal pulse is intensity modulated so that it can be pictured. The phase of the intensity-modulated signals is varied by using 200 c/s saw-tooth waves. For this reason, since the last 30% of the first cycle of the repeater frequency is used for the recovery time of the saw-tooth waves, in this portion an intensity-modulated signal is not obtained. On this account, the effective range finding scope within 1 cycle becomes limited to 70% and as mentioned above only ranges up to 400 km are indicated.

The receiver antenna used for the range finder receiver is a 4 element helical antenna. As the range has increased since the event of KAPPA-8 we have planned to increase sensitivity and use a 4 element configuration. For rockets up to and including the KAPPA-6, the antennas had only 1 element.

(5) Transponder

(a) System. The transponder system is shown in Figure 19. It is divided into two sections; receiving and transmitting.

The receiver section is superheterodyne and combines the 1,685 m/s pulse signal with a local oscillator and a crystal mixer. After being amplified as a 30 Mc/s intermediate frequency, it is detected and the pulse is removed. This is amplified and applied to a blocking oscillator and its output drives the pulse oscillator, which is a combination of a delay line and a thyratron. It is applied to the oscillator tube as a high voltage pulse by means of a transformer. The oscillator is a 5893 pencil tube and transmits directly as a pulse wave with a peak power of approximately 100 W, an amplification of 1μs and a frequency of 1675 Mc/s. The local oscillator tube is a 5794 pencil tube, the thyratron a 2D21W and the rest are all sub-MT heater type tubes. The total number of electron tubes is 10. The required power for the heater is 6.3V, 2.5A and the anode power source is 120V, 70mA.

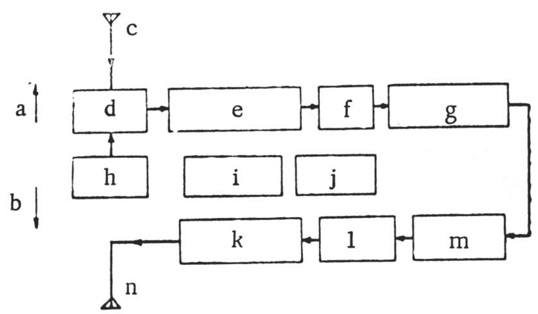


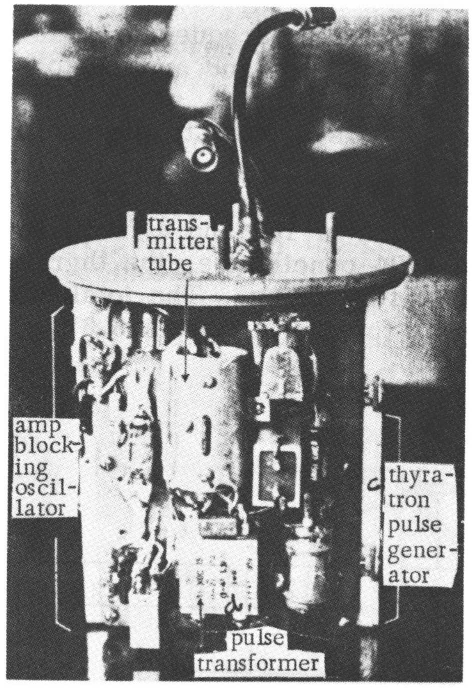
Figure 19. System diagram of transponder.

Legend:

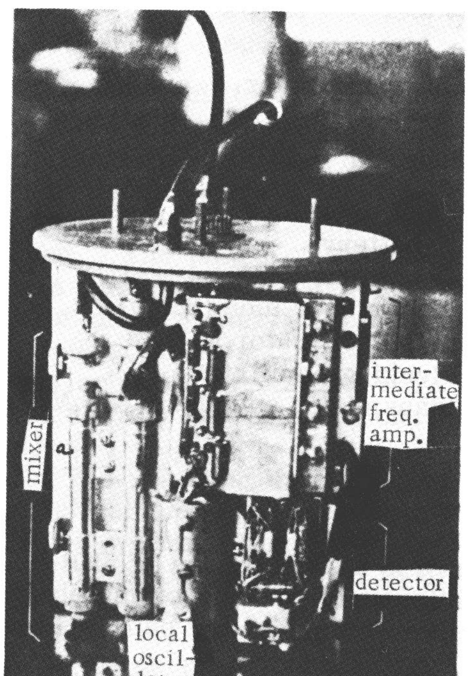
a. receiver section
b. transmitter section
c. receiver antenna 1,685 Mc/s
d. crystal mixer
e. intermediate frequency amplifier (30 Mc/s)
f. crystal detector
g. amplifier
h. local oscillator
i. A-battery
j. B-battery
k. transmitter tube (5893)
l. pulse generator
m. Blocking oscillator
n. transmitter antenna 1,675 Mc/s

(b) Power Source. Power source for A is a straight row of 5HR-3 Yardney silver cells which can be used continuously for approximately 70 minutes. For power source B, a Yuasa silver chloride dry cell is used. Its life is 40 minutes and its weight is 440 g.

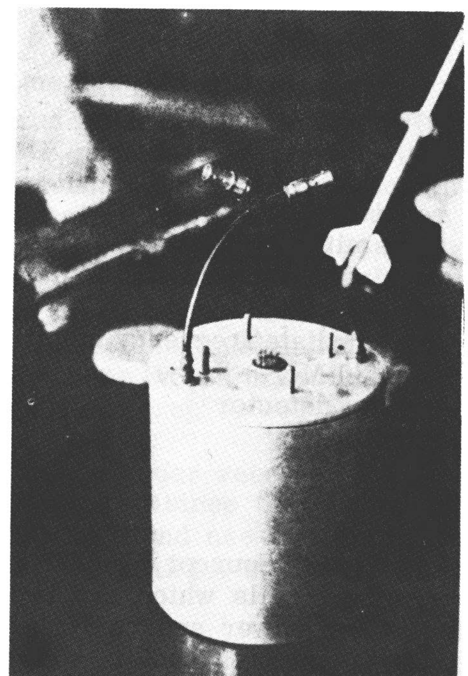
(c) Construction. In a transponder, since the peak voltage of a high voltage pulse reaches above 1000 V, it is especially necessary to pay close attention to electric discharges due to drop in atmospheric pressure. Also, since from a functional standpoint it is impractical to separate the receiver section from the transmitter section, the entire apparatus is



(a) Outer View



(b) Inside (receiver section)



(c) Inside (transmitter section)

Figure 20. Transponder.

enclosed in a durable airtight container as shown in Figure 20. Thus the weight grows bulky, and the present apparatus weighs 3 kg. Its volume is 147 mm x 156 mm.

The electron tubes and circuit parts were mounted on a bakelite baseboard and the system for hardening the elastic compound is the same as for the telemeter transmitter. As far as mechanical strength is concerned, it is no longer a problem but from experience with the KAPPA-8, it is hoped that the airtightness can be perfected, and countermeasures are being taken.

(d) Transponder Antenna. It is necessary to install two antenna systems, one for receiving, and the other for transmitting from the transponder to the rocket. Those points required for the antenna are the same as those related to the telemeter transmitter antenna. However, since the wave lengths used for transponder are much smaller than for the telemeter, the dimensions of the antennas are small and there is considerable freedom in design.

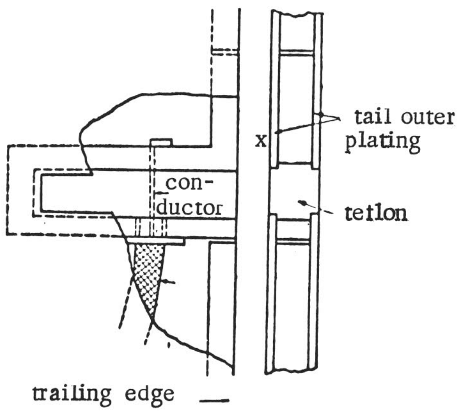


Figure 21. Notch Antenna.

In Figure 21, is the antenna attached to the tail, and is called a notch type. A notch is made at suitable position in the trailing edge of the tail, a cable passes through the inside of the tail, and is fastened to the engine section in same manner as the telemeter. It is attached to both tail fins, one being used for transmission and the other for receiving.

Figure 22 shows the angular antennas attached to the body section. Since the dimensions are small, this much projection does not have an adverse effect on the rocket, and there is an advantage in that time can be saved in attaching the cable. As shown in Figure 23, four are installed, and those opposite one another form a group, and are used respectively for transmission.

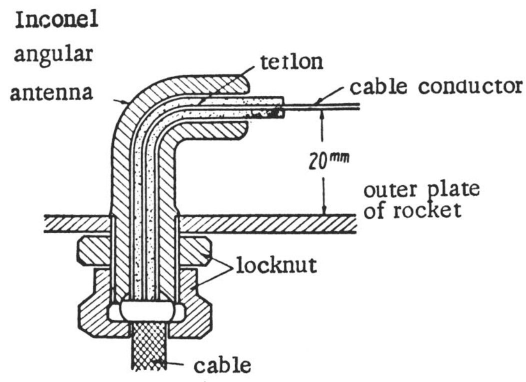


Figure 22. Construction of Angular Antenna for Transponder.

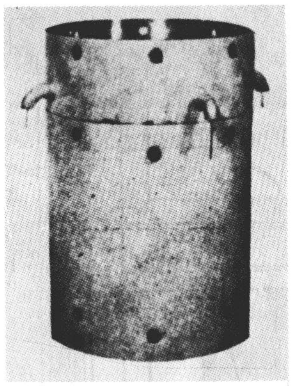


Figure 23. Angular antenna for transponder (150 rocket.

4. DOVAP System

This system obtains the relative velocity from the changes in frequency due to the effect of radio waves, integrates this and plots the distance. The development of this had been planned from the very beginning but its materialization was prolonged due to economy measures. Finally, it was ifrst used in the KAPPA-7, 8D, and 6H1. It was possible to obtain data during flight with the 6H1 up to 100 km. I have decided to give the details on this at a later time, and would like to omit them here.

5. Future Plans

(1) Improving Capability (increasing range)

All of the instruments at the present time are undergoing tests for improving their capability, and even the KAPPA-8 which has greatly surpassed the original range objectives has been tested and its satisfactory operation capability at ranges up to 400 km has been ascertained. However, at the present day when the KAPPA-9 and 10 are about to materialize the time has come for greatly improving capability and increasing range.

The reason that there is a limit to the range, is because the received signals become weaker and it becomes impossible to distinguish them from noise. Consequently, in order to plan for an increase in range, first of all it is necessary to reduce as much as possible the generation of noise, and second to increase the strength of the received signals. The development of a low noise receiver with little noise, is extremely important for this reason. As described in another article, a low noise receiver for radar equipment has been developed and already is yielding remarkable results. The reason that the telemeter equipment capability has improved over the original is because the amount of noise has been reduced to less than 1/4 by using low noise vacuum tubes and by changing the equipment so that the frequency band becomes narrower. Plans are still being made to increase capability. It is not a good idea to increase the power in the transmitter in order to strengthen the received signal, because this calls for excess weight in the rocket payload. It is absolutely necessary to make the receiver antenna larger and increase sensitivity. The use of a four element helical antenna for radar in the KAPPA-8 is one example of this. Below is a general outline of plans for improving capability:

(a) Large Automatic Tracking Radar. At present we are in the process of developing a new automatic tracking radar system having a parabolic antenna with a diameter of 4 m. It will be used for ground transmission, DF, and range finding, being a secondary radar system having a plotting range of over 1,500 km. It can also be used as primary radar, and for this purpose the ground transmission power is 500 kw. Also the servo-machinism is a hydraulic drive and it is expected to be large and have a high response.

(b) Telemeter Receiver and Antenna. In an ordinary FM receiver when the signal-to-noise ratio drops below a certain limit, reception suddenly becomes impossible. This limited value at around 9db, is a basic factor causing noticeable limitation to the range of the FM system. If a frequency negative feedback phase detector-receiver system is used as a countermeasure, we know that the limited value will drop to 10db and even then the range is increased threefold. At present, progress is under way to development of a high capability instrument combined with a low noise receiver for the receiver system, and the manufacture of a 4 element helical antenna for the telemeter receiver. It is expected that the accessible range will be more than 2,000 km. Next year we hope to increase the size of the receiver antennas and are planning for an automatic parabolic tracking antenna with a diameter of 15 m. We expect to reach a range of several thousand kilometers by combining this with a low noise receiver antenna for high altitudes (by cooling the principal parts and reducing the generation of static further).

(2) Increase of Telemeter Channels and Improvement of Transmitter

The present 5 channels were the objective for the KAPPA-6. However in the KAPPA-8 the number of instruments that can be carried has increased and we feel that the present number of channels is inadequate. We are planning to have 10 channels in the near future. At the same time since progress in transistors has been great in our country, we are thinking of designing a small, light weight container with large capacity. In this case, we are planning to transistorize everything up to the high frequency section, but naturally the transmission power will decrease. However, that disadvantage can be amply compensated for by improving the capability of the ground installation.

6. Conclusion

The cooperation and efforts of those concerned with the electronics of the KAPPA rocket has been very great. Especially, we have obtained the cooperation of the laboratories of the Nippon Electric Company, Meisei Denki Company, and personnel from the Komukai Factory of Toshiba, in the trial manufacture of equipment and experiments in Akita. I wish to take this opportunity to express my sincere thanks to them.

In plans for future development, we will be able to obtain the capability anticipated by the concentration of overall effort in all technical fields. I sincerely hope to obtain the cooperation and assistance of those who are now at the Institute in every field.

November 28, 1960