Engineering Notes

Detachable Communications Relay Pods

T. Roseman*
Radio Corporation of America, Camden, N. J.

RAPID and reliable long-range battlefield communications between forward air controllers, combat controllers, and areas under attack must be maintained to insure efficient coordination of all the diverse elements of a modern combat force. Present concepts, utilizing uhf and vhf transceivers, have some serious range limitations imposed by signal propagation characteristics. Detachable Airborne Radio Relay Pods (RRQ-5) were developed and evaluated by the U. S. Air Force to overcome these range limitations.

The RRQ-5 relay pod (Fig. 1) is lightweight, self-contained, and can be hung on any standard underwing 14-in. bomb shackle. These features permit most aircraft to serve as a communication relay.

The development of the relay pod included the following steps: 1) modification of an existing uhf AM radio relay developed for the Navy, 2) modification of a Blue-10 Pod (fire bomb casing) to house the Radio Relay and provide means of attachment to the aircraft, 3) the addition of a turbogenerator to develop a 28-v source, 4) development of suitable antenna with matching network, and 5) development of circuitry within the pod to utilize and control the generated power and to permit the Radio Relay to be completely automatic as well as pilot controlled.

The completed relay pod is 88 in. in length, 13 in. in diameter, and weighs approximately 125 lb. It can be flown at speeds up to Mach 1.2.

Equipment Description

The Radio Relay consists of three basic components, the receiver-transmitter unit, the radio set control unit, and the receiver-transmitter mount.

The receiver-transmitter contains two receiver modules, two transmitter modules, and a d.c.-d.c. power converter module mounted on a chassis that provides the interconnecting and other supporting devices for the modules. These facilities include the intercomponent wiring, relay drives, antenna relays, cooling blower, and filters. All of these subassemblies are housed in a single case, which forms a plenum area for the cooling blower (see Fig. 2).

The weight of this unit is less than 19 lb and measures approximately $5 \times 8\frac{1}{2} \times 17$ in. Some of the salient parameters of this unit are: sensitivity: 5μv or better for 10 db $S + N/N$; power output: 4 w/min; selectivity: ± 25 kc at 6 db, ± 90 kc at 60 db; and stability: ± 10 kc, $-54°$ to $+71°$C.

The radio set control unit contains facilities providing system mode selection, level control of the system audio for monitoring on the aircraft interphone amplifier system, squelch threshold control for the two operating channels, and a visual indication of the transmitting relay channel. All system operating facilities are contained on the front panel that is illuminated by pilot lamps controllable from the dimmer circuit.

The radio set control unit is located in the aircraft cockpit and is accessible to either pilot or other crew member. A front-panel mounted label is used to show the operating frequency of each relay channel.

This communication relay pod operates from its own self-contained power source, consisting of the following main items: 1) ram air turbine d.c. generator, 2) carbon-pile voltage regulator, 3) nickel-cadmium battery, and 4) diodes and circuit breakers.

The d.c. generator provides approximately 28 v which charges the battery through a carbon pile voltage regulator. The voltage then passes through a circuit breaker to the input of the radio relay itself.

Modes of Operation

In the automatic mode of operation, both receiver modules are sensitive to their respective operating frequencies f_1 and f_2. However, in the absence of antenna signal levels greater than those corresponding to the preset squelch threshold levels, no output is generated by either receiver. At this time, both transmitter modules, which also are tuned to f_1 and f_2, are inactive.

Assume now that an amplitude-modulated carrier frequency f_1 greater than the squelch threshold level is received at the antennas of the uhf Voice Relay. The channel A receiver module, which is tuned to f_1, will demodulate the signal and activate the channel A relay driver. When activated, this relay driver will key the carrier of transmitter module B that is tuned to frequency f_2. Simultaneously, antenna transfer relay B is energized to connect the B channel antenna to the B channel transmitter output, and to disable the channel B receiver. Also, the demodulated output of the channel A receiver is amplified and applied to the modulator circuit in the channel B transmitter. Thus, an f_2 carrier is generated to relay information received on carrier f_1.

Upon completion of the f_1 and f_2 message relay, the system reverts to the acceptance status (prepared for reception on either channel). If the next reception is an answer to the previous message relay, an action similar to that already described occurs. However, in this case, the message will be received on carrier frequency f_2, demodulated by the channel B receiver module, and relayed over the channel A transmitting circuitry. Thus, an f_1 carrier will be generated to relay information being received on carrier f_2.

The signal strength necessary to operate the relay system is controlled by adjustment of the squelch controls. The squelch threshold of either channel may be independently adjusted to operate the channel on a signal strength below the nominal minimum signal plus noise-to-noise ratio of 10 db. Although this will result in retransmission of signals of

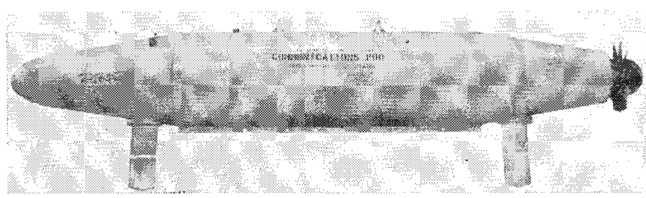

Fig. 1 RRQ-5 uhf AM relay pod.

Presented as Preprint 65-728 at the AIAA/RAeS/JSASS Aircraft Design and Technology Meeting, Los Angeles, Calif., November 15-18, 1965; submitted December 9, 1965; revision received February 10, 1966.

* Engineering Leader, Communications Systems Division.

lowered quality, mission requirements may necessitate this procedure. Modulation signals passed through the uhf Voice Relay may be monitored on an interphone amplifier system aboard the aircraft.

An indication of relay operation is provided by Direction Indicator lights mounted on the front panel of a radio set control unit aboard the aircraft. In the manual mode, signals may be inserted into the relay loop by the pilot or other crewman of the relay aircraft whenever a message relay is not in effect. The relay channel that is to be modulated with the inserted information is selected by means of the mode control located on the front panel of the radio set control unit. The transmitter in the channel selected may then be activated when the aircraft microphone key is depressed. Upon release of the microphone key, both receivers will return to a message acceptance status (essentially automatic mode status), and the pilot or crew member may receive messages on either receiver. The pods have been extensively tested and evaluated by the Air Force. Results of two specific tests are presented here as an indication of the capability of the pod.

Evaluation Results

Test 1

The first test was run with the communication relay pod in an aircraft flying at 10,000 ft, and with two ground transceivers (RRQ-4's) (see Fig. 2). Antenna height was 6 ft and power output was 4 w for all transmitters (station A, B, and Relay). The sensitivity of all receivers in this system was 5 μv.

Transmitter frequency from the ground station A was 267.8 mc, and transmitter frequency from ground station B was 342.3 mc. The theoretical maximum range using the line of sight formula is

$$R = 1.23\ 10{,}000^{1/2} + 1.23\ 6^{1/2} = 123 \text{ miles}$$

Using value of $Pt = 4$ and sensitivity of Relay Receiver at 5 μv or $e_0 = 2.5$ μv, the attenuation is then equal to $= 10 \log 4/(2.5)^2\ (50 \times 10^{12}) = 10 \log(32 \times 10^{12}) = 10\ (13.52)$. The attenuation is therefore equal to 135.2 db. At 135.2 db and 300 mc, the average range is 170 naut miles.

Now assuming losses of about 7 db for such items as degradation in sensitivity, power output and null out point, the attenuation is now 128 db, and the theoretical range is therefore about 100 naut miles. The experimental results obtained from this test indicate a range of approximately 50 naut miles from station A to the Relay and 30 miles from the Relay to station B.

Although the results of the test do not meet the expectations of the theory, the range of 80 naut miles between ground stations attained in this test was considered good, especially since 7 naut miles was the normal range of communications between the two ground stations. It must therefore be assumed that an additional 6 db was lost because of the heavily wooded area surrounding the ground transmitter. This is not an unreasonable assumption, based on prior experience.

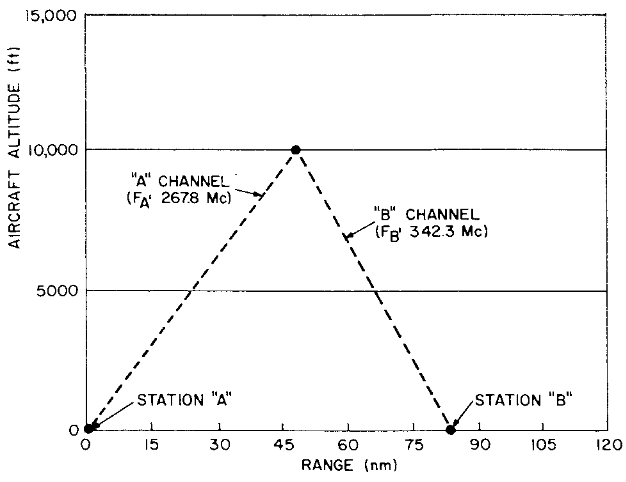

Fig. 2 Maximum relay range between two backpack portable transceivers, RCA Model RRQ-4.

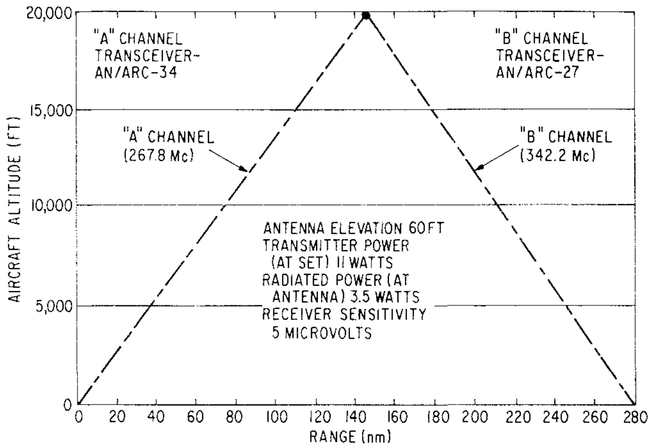

Fig. 3 Maximum relay range between two fixed ground stations, AN/ARC-27 and AN/ARC-34.

Test 2

The next test performed was with ground transmitter A (AN/ARC-34), having a radiated power output of 3.5 w and elevated to a height of 60 ft, whereas the communication relay pod was on an aircraft flying at 20,000 ft (see Fig. 3). Ground receiver B (AN/ARC-27) had a sensitivity of 5 μv.

Using the line of sight formula, the theoretical maximum range is

$$R = 1.23\ 20{,}000^{1/2} + 1.23\ 60^{1/2}$$

$$R = 185 \text{ naut miles}$$

By using the attenuation formula with $Pt = 3.5$ w and $e_0 = 5$ μv, the attenuation is then $= 10 \log 3.5\ (2.5)^2\ (5.0 \times 10^{12}) = 134.5$ db. Using the graph on Fig. 3, and at 134.5 db and 300 mc, the average range is 200 naut miles. The actual range attained in this test was 140 naut miles (see Fig. 3) from station A or B to the relay, or a total of 280 naut miles between stations A and B. As the transmitter in the communication relay had a power output of 4 w and the sensitivity of the ground receiver (B) was 5 μv, the range from Fig. 4 also is approximately 200 naut miles.

Conclusions

Communication relay pods extend the range of communications significantly. Factors such as antenna losses, null points, and poor location of ground antennas prevent the system from attaining its theoretical maximum limit. With the development of relay pods, aircraft easily can be modified to serve as a communication relay, since little modification of the aircraft itself is required. As the pilot of the aircraft has the break-in capability, radio relay pods permit an aircraft to carry an added means of communication. In aircraft where space is at a premium, this could be an important factor.

As a result of the evaluation tests performed by the Air Force, areas of suggested improvements in the RRQ-5 are noted below: 1) provisions for additional channels, and 2) an increase in power output. By an extension of the communication Relay Pod principle, it is theoretically possible to extend the range of communications over any desired range with the use of a number of radio relay communication pods, so long as the relay stay within the range determined by the system attenuation.