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# GROUND-TO-AIR COMMUNICATION USING MARK X IFF

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OTTAWA

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## ABSTRACT

A system whereby emergency ground-to-air communications can be established with Mark X IFF equipped aircraft, with little or no interference to normal IFF operation, has been tested in the laboratory. Pulse-frequency modulation is used, with a carrier consisting of double pulses spaced 11 microseconds at a mean PRF of 6000 pulse-pairs per second. These pulses would be transmitted from a modified ground interrogation unit with a steerable antenna. In the aircraft, a decoder-demodulator circuit employing one tube envelope and weighing about two pounds, is connected to a video test receptacle on the IFF unit. No modification of this unit is necessary. Provision can be made to indicate automatically to the pilot that the system is in use. Suggestions for operational employment of the system are given, and it is recommended that flight tests be carried out.

# GROUND-TO-AIR COMMUNICATION

# USING MARK X IFF

— J. R. Kenney —

## GENERAL DESCRIPTION OF THE SYSTEM

The suggestion that the interrogation link of the Mark X IFF system might be used for ground-to-air communication, on an emergency basis, originated with S/L D.L. Dudley of the Directorate of Radio Warfare, RCAF Headquarters. An investigation has been made by the National Research Council (Project No. C-37-28-01-05), and it has been determined that such a means of auxiliary communication can be provided simply in Mark X equipped aircraft, while meeting the requirements of little, if any, interference with normal IFF operation, minimum added airborne equipment (possibly two pounds), and no modification of the AN/APX-6 airborne transpondor. The abbreviation "CUFF", meaning "Communication Using IFF", will be used for the system in this report.

The technique to be described is essentially the use of pulse-frequency modulation of an auxiliary ground interrogator with a separate antenna, steerable on to the bearing of the aircraft concerned. Double pulses spaced at 11 microseconds are generated at a mean rate of 6000 pulse-pairs per second, and this rate is modulated by the voice frequencies to be transmitted. With a 6000-cps pulse carrier, voice frequencies are limited to 2 kc/s to prevent undue intermodulation distortion. However, this provides more than adequate quality for this type of communication. Since the spacing of these double pulses is different from the spacings used for normal interrogations the transpondor trigger circuits are not affected. In the aircraft these pulses appear as video pulses at a low impedance level at the video test receptacle (J-104) on the front of the APX-6. A coincidence decoder and amplifier (one tube envelope) and a low-pass filter are then used to recover the voice frequencies. Thus, in the aircraft, the APX-6 serves as the receiver for this communication system, and requires only the addition externally of a small box which may be located at any reasonable distance from the APX-6.

It is obvious that a number of separate channels could be obtained by providing different pulse spacings, if it should prove operationally suitable and necessary to have different ground transmitters operating on different channels, or to restrict certain CUFF transmissions to one particular aircraft or group of aircraft.

## INTERFERENCE

In operation it is expected that interference between CUFF transmissions and IFF interrogation pulses will be restricted to aircraft lying within a few degrees of the bearing of the CUFF antenna, and bench tests have shown that the interference at worst should be quite tolerable. Because of an echo-suppression circuit in the transpondor, a received pulse following another within about 5 microseconds may be suppressed, depending upon the relative amplitudes of the two pulses. For equal voice and interrogation signal strengths, the trigger failure rate from this cause is 6% for a 400-cps interrogation rate. The trigger failure rate can become as high as 35% if the voice-pulse level is 40 db above a minimum interrogation level. This could occur only when a distant ground interrogator was competing with a nearby CUFF transmitter. Chance coincidences between the CUFF and interrogation pulses can result in a premature reply, the error being equal to the challenge-pair spacing in use. Since the number of these errors will be less than about 4% of the normal challenge rate of 200 or 400 per second, the effect again is not serious. No evidence of spurious responses due to noise and CUFF signals, or due to CUFF signals alone, has been found. The double pulse feature of CUFF results in a low level of interference with CUFF by normal use of IFF. A simpler single-pulse system would suffer considerable interference in that the interrogation pulses would be heard whenever a challenge beam swept through the aircraft position. However, the quality with single pulses remains high, and the airborne equipment is reduced about one-third in size and weight, owing to the elimination of the decoding delay line.

## OPERATIONAL ASPECTS

During the course of the investigation, certain ideas arose as to the possible operational employment of CUFF, and these are given here as suggestions for consideration by the RCAF. There seem to be two roles for CUFF: one following failure of the normal communication equipment, and the other where normal facilities are being jammed. In either case the failure or interference may be noticed in the air, or on the ground, or in both places. If the failure is noticed in the air, the "Emergency" reply feature of the Mark X system can be employed and part of the standard ground procedure for dealing with "Emergency" can be the use of CUFF transmissions. With the introduction of SIF, other methods of signalling a request for CUFF can be devised. No return link is proposed for CUFF, as SIF will provide coded responses, some of which can be used for this purpose. If the failure in communication is noticed on the ground, CUFF transmission can be used at once, provided either that the pilot can be warned that CUFF transmissions are being directed at or near him, or that CUFF signals can be connected automatically to the intercommunication system of the aircraft. A circuit is described later by which either or both of the above functions can be achieved with the addition of a plate circuit relay and a half-dozen small components.

In the event of jamming, either the air-to-ground link is jammed as well, in which case the ground knows about the trouble, or else this link is clear and the pilot can report the trouble. It appears unlikely therefore that the "Emergency" response would have to be used to request CUFF under conditions of jamming. Thus the only extension of the use of the "Emergency" facility beyond its present employment might be in situations where a communications failure endangers an aircraft.

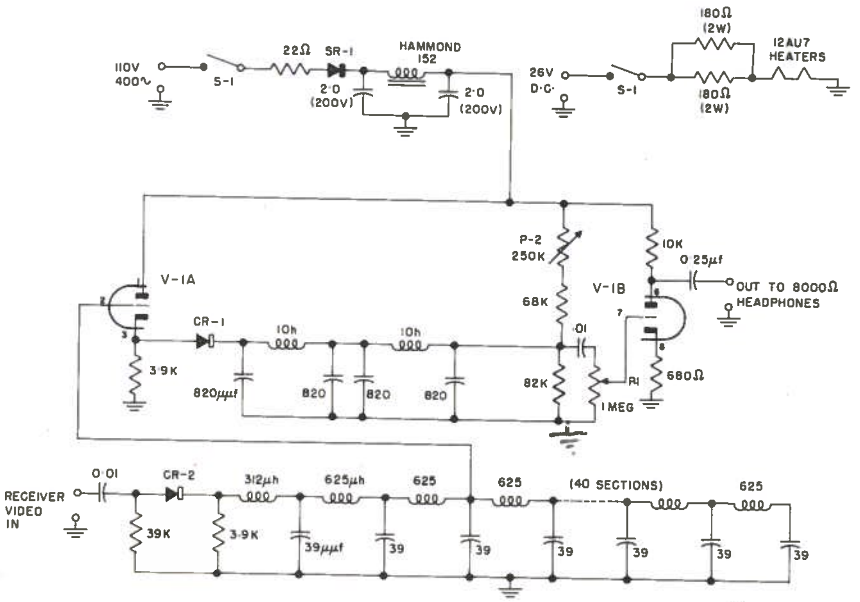
## GROUND EQUIPMENT

It is anticipated that a modified AN/APX-6 transpondor or a standard AN/UPX-6 interrogator can be used as a CUFF transmitter. A preliminary investigation indicates that at the voice carrier PRF of 6000 pulse-pairs per second, these units can deliver at least 300 watts peak power without exceeding the average power dissipation of the modulator or oscillator tubes. Trigger pulses for the transmitter can be obtained from a circuit employing a multivibrator, the frequency of which varies linearly with grid voltage. The rate of the multivibrator can thus be frequency modulated by voice frequencies from a microphone and audio amplifier. The square waves from the multivibrator are differentiated to trigger a blocking oscillator, the output of which fires a second blocking oscillator through an 11-microsecond delay-line. The outputs from the two blocking oscillators are then used to trigger the modulator of the transmitter.

Whether or not the power capabilities of the AN/APX-6 or AN/UPX-6 will prove to be sufficient in practice cannot be definitely settled until the available ground antenna gain can be determined. It appears that an antenna giving higher gain than, for example, the AS-295 can be usefully employed for CUFF, particularly since some vertical directivity can probably be used. If a standard antenna were used, the CUFF system would be 3 to 6 db weaker than the IFF challenge link depending on which CUFF transmitter was employed.

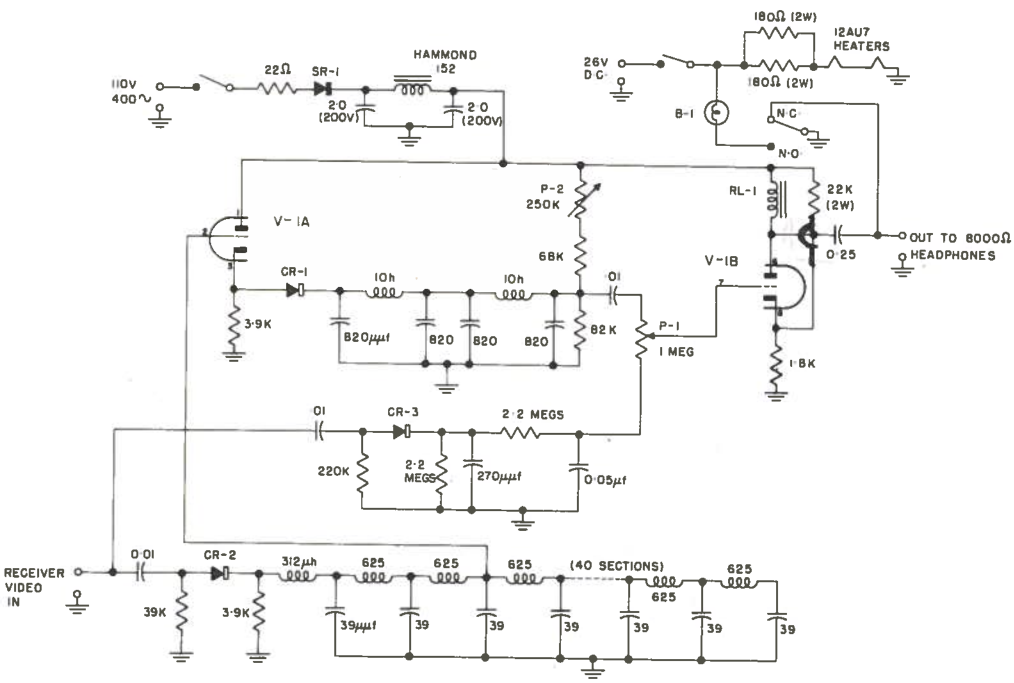
## AIRBORNE EQUIPMENT

The airborne demodulator circuit is shown in Fig. 1. Positive video pulses, about 60 volts in amplitude if the R.F. input signal strength is sufficient to cause limiting, are coupled from the receiver video receptacle to the decoding delay-line. The delay of the 40-section line is about 6 microseconds and the characteristic impedance is 3.9K ohms. Since it is unterminated, pulses impressed upon the line are reflected without change in polarity. The line is fed through a crystal-diode CR-2, hence reflected pulses "see" only the 3.9K ohm resistor at the input to the line, and no further reflections occur. If, at some point on the line, an incident pulse meets the reflection from a previous pulse, the pulse amplitudes add. For 11-microsecond pulse separation and the delay-line shown in Fig. 1, this addition occurs three sections from the input and this point is connected to the grid of the cathode follower stage (V-1A), which drives a low-pass filter (2 kc/s cutoff) through the crystal diode CR-1. The diode is biased by a bleeder current through the 82K terminating resistor of the filter, so that only the larger pulses from the addition of the 11-microsecond pulse-pairs are passed to the filter. A preset adjustment of this diode bias is provided by P-2 so that undesired single pulses will be barely audible in the headphones. In addition to this function, the diode CR-1 stretches the pulses at the filter input in order to increase the audio voltage available at the filter output. The filter output containing the voice frequencies is fed through the gain control P-1 to the grid of the audio amplifier stage (V-1B) whose output is sufficient to drive a pair of headphones. In actual practice, the demodulator would probably feed into the




V-1 12AU7
CR-1 IN75
CR-2 IN38A
SR-1 FEDERAL 1004A SELENIUM RECTIFIER

FIG·1 CUFF DEMODULATOR WITH 11-MICROSECOND DECODER




V-1 12AU7
CR-1 IN75
CR-2 IN38A
CR-3 IN38A
RL-1 RELAY (10K,2ma)
B-1 24V BULB
SR-1 FEDERAL 1004A SELENIUM RECTIFIER

FIG·2 CUFF DEMODULATOR WITH 11-MICROSECOND DECODER AND AUTOMATIC INDICATOR intercommunication system of the aircraft, and an output matching transformer would have to be provided.

In Fig. 2, a circuit for automatic indication or switching, or both is shown. A detector-integrator network is connected to the input video signal through a crystal diode CR-3. The time-constants of the network are so chosen that with 60-volt pulses, the D.C. voltage across the 0.05 microfarad capacitor increases from 1 volt at a PRF of 400 cps to about 13 volts at 6000 cps. Since the volume control P-1 is returned to this point, this D.C. voltage is applied to the grid of the amplifier stage (V-1B), in which the coil of a plate-circuit relay replaces the 10K plate load. The 22K bleeder resistor and the cathode resistor of V-1B are so chosen that the relay is not energized unless the PRF exceeds 3000 cps. When the coil is unenergized, the normally closed contact of the SPDT relay short-circuits the audio output to ground. When the PRF exceeds 3000 cps as in a CUFF transmission, the relay is energized, removing the short circuit from the amplifier output and also lighting an indicator pilot bulb. Either automatic switching or indication, or both, are thus readily available.

The B+ power for the CUFF attachment can be obtained from a 110-volt A.C. 400-cps supply with a selenium rectifier, the A.C. power requirement being about 1.5 watts for the circuit of Fig. 1, and about 2.3 watts when the automatic indicator is added. Filament power could be obtained from the 26-volt D.C. power supply of the aircraft, and with a suitable dropping resistor, the D.C. power requirement would be 4 watts.

## CONCLUSIONS AND RECOMMENDATIONS

Laboratory tests have shown the feasibility of using the airborne IFF receiver in a system to provide emergency communication from ground-to-air without undue interference to the normal IFF function. Further, the system appears to be highly desirable in that it provides this link, of good quality, with very little additional airborne equipment. It should be noted that no demands are made on the transpondor duty cycle since no air-to-ground transmissions are involved.

It appears unlikely that any additional useful information can be obtained from bench tests, and it is recommended that if further development is warranted, a program of flight tests be instituted by the RCAF in cooperation with NRC.

## ACKNOWLEDGEMENT

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