DAGMAR

Drift and Groundspeed Measuring Airborne Radar

MEASUREMENT of ground speed and the true motion of an aircraft over the earth's surface, a longtime navigation problem, can now be made directly and accurately due to the development of a new radar aid by the Defence Research Board scientists.

Known as a Drift And Groundspeed Measuring Airborne Radar (DAGMAR), the 100-pound equipment developed at the Electronics Laboratory*, fits readily into the base of an aircraft's fuselage (development prototypes have had their airborne trials fitted into the rocket bay of a CF-100).

Changing Frequency: The new equipment employs the Doppler principle, a physical phenomenon relating to the change in frequency apparent to the receiver of radio and other waves transmitted from a moving source. DAGMAR directs radio waves at the terrain at predetermined geometric angles, and in this way is able to ascertain both groundspeed and drift angle. A combination of groundspeed and drift angle results in a track measurement.

B. A. Walker, Deputy Chief Superintendent of the Defence Research Telecommunications Establishment, and R. Keith Brown, led the team which developed DAGMAR.

Credit for an assist has also been given to the Canadian Marconi Co., which acted as industrial contractor, and in this capacity helped to decrease the bulk of the unit by developing an efficient, continuous wave transmitter requiring considerably less power than that previously used. Low power signal transmission has resulted in a lessening in bulk.

DAGMAR operates satisfactorily in flight at altitudes of over 40,000 feet.

*The Electronics Laboratory is one of the two Ottawa units comprising the Defence Research Telecommunications Laboratory.

Developing DAGMAR

By B. A. Walker and R. K. Brown

A PROBLEM which has always existed in aircraft navigation is that of measuring the aircraft groundspeed and track. Instruments exist which provide airspeed and heading, but in order to calculate groundspeed and track the navigator must determine the correct wind speed and direction. Since a reliable wind speed is difficult to obtain, a much more satisfactory and accurate solution to the problem would be to measure groundspeed and track directly.

A radar system using the Doppler principle can be used to do just this. When an observer hears a sound from a vibrating source — such as a whistle — which is moving towards him, he will hear not the true pitch (or frequency) of the whistle, but a slightly higher pitch. In fact, whenever the distance between the sound source and the observer is changing, the pitch which the observer hears will always be different from that of the source . . . higher when the distance is decreasing and lower when the distance is increasing.

Increase or Decrease: This phenomenon is not confined to sound waves. It is also observed when light waves and radio waves are transmitted and received. The amount by which the frequency appears to have been increased or decreased, which we will call the "Doppler" frequency, is directly proportional to the speed of the transmitter toward or away from the receiver. In the case of the radio waves, the relation between the speed and the Doppler frequency is given by:

$$fd = \frac{FV}{C}$$

where fd = Doppler Frequency
F = Transmitter Frequency
V = Velocity of Approach (or Recession)
C = Velocity of Electromagnetic Radiation

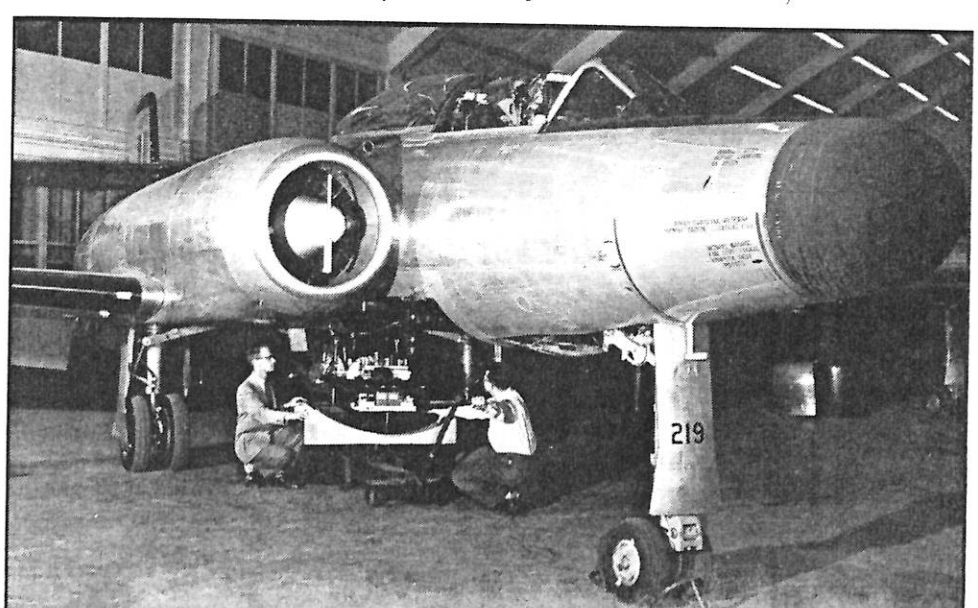


Photo shows experimental model of DAGMAR being fitted into the rocket bay of a CF-100 prior to airborne trials. L to R are J. D. R. Boulding and E. L. Stafford, members of DRB team that developed the new navigation aid.

Now let us return to our navigation problem. We wish to measure the aircraft ground speed and track with a completely self contained system. We have in the aircraft a radio transmitter operating at about 10,000 Mc and producing a beam which is aimed forward and down. This beam will be scattered by the earth and some of the energy can be received back at the aircraft.

Because the aircraft is not flying along the transmitted beam and because here are effectively two Doppler shifts in frequency — one when the waves are received at the ground and a second when they are received back at the aircraft — the relation between ground speed and the Doppler frequency becomes:

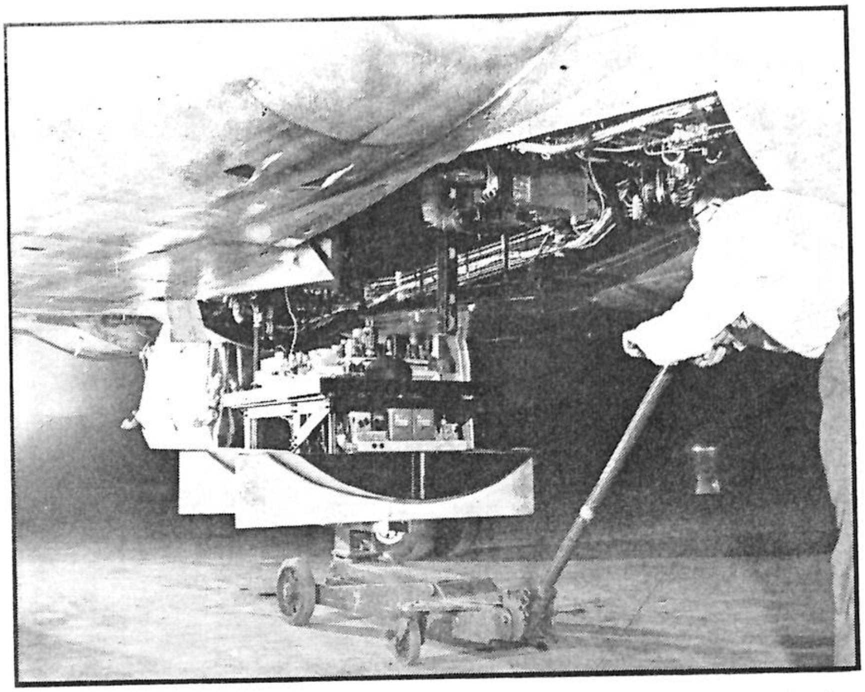
$$fd = \frac{2F\ Vg \cos \phi}{C}$$

where fd = Doppler frequency
F = transmitter frequency
C = velocity of electromagnetic radiation
Vg = aircraft ground speed
ϕ = angle between the aircraft velocity vector and the direction of the radar beam

fd, then, is a direct measure of the aircraft ground speed. We have not yet determined track. This the Doppler cannot do directly, but it can measure drift angle and with the addition of heading, produce track.

Two Beams: Suppose that instead of a single radar beam directed forward and down we have a pair of beams, one directed slightly to the right and the other to the left of the centre line of the aircraft. If the ground track of the aircraft is not along heading (i.e. if there is drift) one of the beams will produce a higher Doppler frequency than the other. All that is required then is that our radar system compare the Doppler frequencies from each beam and rotate the antenna producing the two beams until they straddle track symmetrically and the two Doppler frequencies become equal. The angle between the antenna and the center line of the aircraft is the desired drift angle.

One further improvement on the simple system described above is worth mentioning. Let us suppose that an aircraft carrying a radar with a single beam directed forward and down climbs instead of flying horizontally, and that the antenna is maintained horizontal so that the radar beam makes the same angle as before with the surface of the earth.



Close-up shows DAGMAR in process of being jacked up into CF-100 rocket bay. Weight is now 100 lb., but miniaturization is expected to cut this to 70 lb.

The resultant Doppler shift is now the result of two motions (if we consider the aircraft climb to consist of a horizontal and a vertical component of velocity). The radio wave received back from the earth will be increased in frequency due to the horizontal motion, but decreased in frequency due to the vertical motion, since this motion increases the distance between transmitter and receiver. Our radar system will not measure the same Doppler frequency that it would for horizontal flight and so the measurement of ground speed will be in error. We can overcome this error if we arrange a second beam directed down and to the rear of the aircraft. If we use the sum of the Doppler frequencies from the forward and rearward beams as a measure of ground speed, vertical motion of the aircraft is exactly compensated for, and we obtain true horizontal speed. A beam system such as this is usually referred to as a "Janus" system, after the Roman god who looked both ways. In addition to the advantage described here, other very important technical improvements are obtained by the use of a Janus system.

Four Beams: The Doppler radar developed by the Electronics Laboratory has four beams, left forward, right rear, right forward and left rear, so that the advantages of the Janus feature can be obtained in a system which also measures drift. In order to avoid the necessity of four antennas, a switching system is used so that only two beams are on at a time. This is arranged so that the left forward and right rear are on together for one half second and then the right forward and left rear beams.

Two major problems confront the designer of a Doppler radar:

(a) When flying at high altitudes to obtain a strong enough signal for satisfactory ground speed measurement and . . .

(b) To achieve this with a system which is light and compact.

The first Doppler radar systems developed used short pulse radar transmitters with peak powers of several kilowatts. This resulted in systems which were bulky and heavy. In the Electronics Laboratory every effort has been directed toward a light-weight system, and this has been achieved mainly in two ways. First, a significant improvement in technique of C. W. radar developed by the contractor, the Canadian Marconi Co. has resulted in a radar that produces reliable ground speed measurements at high altitude with transmitter powers of a fraction of a watt. Such a reduction in

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small sense antennas and where maximum operational range is desirable. Both Navy and Army and Air Force groups are evaluating production units of the 21.

List price is $2633. un-installed. Two of the first production subminiature radio compasses are installed in ARC's new Beechcraft Twin-Bonanza demonstrator and one each on its Bonanza and Navion. The deHavilland Aircraft of Canada Ltd. has a Type 21 in its demonstration Beaver and are reported to be pleased with its performance and reliability.

DAGMAR

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transmitter power is accompanied by a marked reduction in power supply weight and size and the elimination of the bulk and high voltage problems associated with high power pulsed magnetrons.

Secondly, a transistorization program, carried out by the transistor section of the Electronics Laboratory, has resulted in circuits which replace most of the vacuum tubes. This conversion further reduces the power supply size and weight and greatly increases the system reliability. These two advances in the art produce a light-weight low power Doppler radar capable of satisfactory operation up to altitudes greater than 40,000 feet.

The vacuum tube version of this system, which has had many hours of successful flying, weighs 100 lbs. It is expected that with the adoption of the miniaturized transistor circuits the weight will easily be reduced to less than 70 lbs.

WINGED RESCUERS

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that the loud hailer can be heard four or five miles despite heavy forest cover.

The crews of OPAS aircraft do not necessarily have to depend upon "Ground Support" to effect a rescue as in the case of the hunter. The aircraft are all seaplane versions of the Beaver, and can operate out of a lake as small as a quarter mile in length. Last August two teenage girls failed to return from a hunt for an abandoned copper mine. They had been out some 24 hours before the Air Service was notified, and within an hour the two were located. Showing great presence of mind, the girls had remained in the general area they were originally thought to be heading, and had found a small hill where they sat to wait rescue. The pilot, used the same procedure to find the girls and in directing them to a small nearby lake. Once they had gained the shore line, however, the Beaver was landed, the girls bundled on board and within minutes were enjoying their first full meal in many hours at the Parry Sound Base.

Government agencies throughout the nation are carrying out similar operations, covering the vast northland territories from coast-to-coast as best they can, despite circumstances of being under-staffed and under-equipped. A primary task of all Provincial Air Service Departments is the conservation of Canada's valuable forest areas. Fire patrols are carried out continuously during the dry season, and millions of dollars of lumber have been saved through the prompt action of these patrols by water-bombing an outbreak to contain it until fire fighters can be flown in to the area.

Air routes in the north have speeded the opening and exploitation of the untold riches of this silent land. The men and aircraft are bringing civilization to a "new country", but above all they are cheating the elements of their toll of human life and natural resources—Canada's economic potential is developing through the air, it is being protected from the air.

COMING EVENTS

April 22-24—Vickers Inc. Annual Jet Engine Hydraulic Symposium, Hotel Statler, Detroit.

April 25-26 — AITA Semi-annual Meeting, Empress Hotel, Victoria, B.C.

May 6-10—Industrial Tool & Production Show, Exhibition Park, Toronto.

May 22-24—Annual Convention, American Society for Quality Control, Masonic Temple, Detroit.

May 27-28—Annual General Meeting, Canadian Aeronautical Institute, Chateau Laurier, Ottawa.

June 8 — Air Force Day across Canada.

June 24-25—29th Meeting, Aviation Distributors & Manufacturers Assoc., Grove Park Inn, Colorado Springs, Colo.

September 9-13—IATA Annual General Meeting, Madrid, Spain.

Sept. 30-Oct. 4—Canadian National Materials Handling Show, Show Mart, Montreal.

October 2-4—Annual Meeting and Forum, National Business Aircraft Assoc., Cosmopolitan Hotel, Denver, Colorado.