2.12. ATC AND BIRD RADAR SURVEILLANCE WITHOUT TEARS

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"ATC and Bird Radar Surveillance without Tears"

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1. Introduction

There is no doubt that to restrict flying during Spring and Autumn migration and during periods of intense local bird activity is likely to reduce the birdstrike rate in any country. But although these periods of bird movement are fairly well defined factors like the weather can stop or change their timing. By keeping a watch on the ebb and flow of bird movements with radar and visual means, the application of flying restrictions can be properly phased and their duration minimized. If there is a strong correlation between the intensity of PPI echoes representing birds, the birdstrike rate, and the bird mass in strike (i.e. either large and heavy birds or spatially dense flocks), there is always a strong likelihood that each echo will represent a bird or flock that could produce a damaging birdstrike. Under such conditions it is possible for a PPI echo intensity level to be found above which the probability of birdstrike becomes very high and flying restrictions become necessary. It is convenient to judge the intensity level of bird echoes in the case just mentioned by making use of simple PPI-photographic methods and from data obtained on conventional ATC radars.

Already bird warning messages based on such radar information are being issued as NOTAMS between European countries, and tentative proposals are underway with ICAO for making use of conventional ATC radars and simple assessment methods for gauging the birdstrike risk.

It is probably a timely moment to consider the limitations imposed on bird warning schemes by using conventional ATC radars and simple PPI assessment methods and discuss ways of overcoming some of these limitations.

One of the first limitations of using conventional ATC radars relates to the echo on the PPI and the bird, or number of birds, the echo represents in the sky. There is no direct method of relating the size of an echo on the PPI with the size of a bird, or the number of birds, in the radar beam. The smallest object that can be resolved by a radar is a volume in space called the radar pulse volume or the radar resolution cell, which is proportional to radar range, transmitted pulse length, and the vertical and horizontal beamwidths of the aerial. The dimensions of the resolution cell of a conventional ATC radar can be very large indeed; a typical volume 6oo metres high by 3oo metres wide and 4oo metres long = 72 million cubic metres at a radar range of 2o nautical miles. Such a resolution cell could contain many birds spaced out or bunched in flocks, but unless their spatial distribution exceeds the horizontal dimension or the pulse length dimension of the cell they will appear as a single echo with nothing to distinguish if the cell is occupied by 5 wild duck, 5o gulls or 5oo starlings. The size of the radar resolution cell and that of the PPI echo are in fact dependent upon radar parameters and independent of target size. Only when the dimensions of the target exceed the dimensions of the cell is the event revealed by a corresponding overlap of the PPI echo dimensions. Then the echo is dependent upon target size or spatial distribution.

A second limitation relates to the PPI intensity assessment method and is the consequence of the small range of intensity ratios (from the threshold of a barely discernable echo in receiver noise to a limiting echo painting brightly on the PPI screen) that can be accommodated on the typical PPI. For example, if a radar resolution cell, contained 1o gulls and the echo on the PPI had reached the limiting level it would paint up the same echo intensity as 11 or 1oo gulls occupying a similar cell at the same range and moving in the same direction. Problems with the PPI intensity method do not stop with the limitations already mentioned. Faulty setting-up of the PPI using subjective methods, the different requirements of the human eye and the photographic film and incorrect photography and photographic processing, can reduce the recorded radar detection range and the echo intensity. It is quite easy to reduce the range coverage by more than 4o% and the intensity rating from 7 to 3 in this way. The use of ground clutter removal techniques, like MTI, introduce just another variable in the assessment of echo intensity making it more and more unlikely that quantitative and repeatable measurements can be obtained.

A third limitation relates to the lack of angular discrimination in the vertical plane with the consequence that it is impossible to say whether there are 5 or 5o birds stacked one above the other in the resolution cell. The lack of heightfinding precludes the possibility of judging whether a bird movement is on a conflict source with an aircraft.

A fourth shortcoming experienced by the conventional ATC radar when used for surveillance of bird movements can be that the range cover is inadequate on birds, because the radar parameters were selected for and optimised on faster and higher flying aircraft. In addition, a radar satisfactorily sited for air traffic control may have serious "holes" in the vertical coverage diagram or "cut-off" sectors in the horizontal coverage diagram at low altitudes making it impossible to detect low flying birds.

A fifth limitation to the use of any ATC radar is that day to day ATC radar work takes precedence over bird movement surveillance, of which it takes little account. Consequently, bird surveillance records are often spoiled by changes in radar working conditions made during routine ATC operations.

The way round all the radar limititions in the first place is not a new bird radar, a radar expert or a bag og gold, but a positive philosophy. Air safety and ATC are closely related subject, and if radar surveillance of bird movements is necessary for air safety it must be dealt with from within the framework of air traffic control. There is no doubt that the orders for bird-scaring on an aerodrome emanate from the ATC tower and it is from there the control of radar for bird surveillance must be supervised, even during the experimental phase. The problems of precedence disappear once the ATC authorities are responsible for making radar surveilance of bird movements. I think we should congratulate our French colleagues for their wisdom in adopting this philosophy from the start.

In the remainder of my paper I am going to show how difficult it is to obtain any quantitative measurement of echo intensity when MTI is used, and then, I shall demonstrate a quantitative method of measuring echo intensity. The method utilizes an additional receiver, which as it by passes existing receivers used for routine ATC operations, enables both ATC and Bird Radar Surveillance to be made without mutual interference and conflict. The special intensity measuring receiver feeds a magnetic tape recorder, which can be decoded by means of a digital computer. The intensity data can be referred to a calibrated 8-point scale and printed out in the form of a bird intensity chart. The PPI-photographis method is retained for the qualitative recording of bird movements only and consequently the effect of lost film will be much less serious.

2. MTI Effects

Moving target indication (MTI) is a method of eliminating unwanted fixed target echoes generated by hills, buildings and power lines without getting rid of wanted target echoes like aircraft. MTI systems fitted to ATC radars are disigned to retain aircraft moving at speeds above a hundred knots but not relatively slow moving targets like birds. Nevertheless, althoug few MTI systems eliminate birds entirely from the PPI they all affect the intensity of bird echoes in an adverse way that makes repeatable quantitative measurements difficult or impossible. The intensity of a bird echo is affected by the bird's radial velocity. This is a vector quantity having a magnitude equal to the bird's speed and a direction which is radial with respect to the radar. The degree that the echo intensity is affected by these two components depends upon the parameters of the radar, especially the radar wavelength.

Fig. 1 shows the MTI response diagrams for 1o,23 and 5o cm wavelength radars. The vertical scale of the diagram is of the relative echo response of the radar with and without MTI. The horizontal scale of the diagram is in terms of radial velocity of the target in knots. Targets moving on a radial course suffer the changes in echo strength or intensity shown on the curves, when the radar is switched on to MTI. Of course, when the MTI is not operating the echo intensity does not change with target velocity. Note that the MTI response and the echo intensity are zero when the target velocity is zero and enho intensity increases as target velocity is increased. The 1o,23 and 5o cm radar curves go through zero amplitude (corresponding to no loss in signal) at radial velocities of approximately 1o,25 and 5o knots respectively. The response and echo intensity suffers a severe reduction of 1/3 (equivalent to - 1odB) or more, when target velocities are less than 5, 12 and 25 knots for radars operating at wavelengths of 1o, 23 and 5o cm respectively. The curves demonstrate that echo intensity is related to target radial velocity in a complicated way and that the loss in echo intensity will be serious on a 5o cm radar for birds flying at radial velocities of less than 25 knots.

Far the greater number of birds in any bird movement fly past the radar on tangential courses and only a small percentage of the birds fly over the radar on radial courses. If a target flies on a tangential course, as per diagram Fig. 2, at any point A or B the radial component of velocity with respect to the radar is v_t sin . The radial velocity component generated by a target flying tangentially with respect to the radar is always less than its tangential velocity by the factor sin which is zero when angle is zero degrees, and which increases with increasing values of angle , until sin tends toward unity as angle tends towards 9o derees. Once the radial velocity component for a tangential target has been resolved by applying the sin factor it is possible to evaluate changes of echo intensity from the curves shown in Fig. 1. Generally, we find that the tangential target must fly faster by the factor $(\sin\ )^{-1}$ to obtain the same echo intensity as the radial target.

The effect on the PPI desplay of this MTI "course" factor on a large movement of birds flying on parallet tracks to one another and over the radar is illustrated in Fig. 2. In either side of the direction of movement there is a "MTI wedge" where the echo intensities are zero for birds flying tangentially and broadside-on to the radar, bur where the echo intensities are relatively high for birds flying on a radial course. The wedge is proportional to angle and it can be very wide for slow moving birds when a 5o cm radar is used. The wedge angle is less if faster birds are involved of if they are aided by a tail wind. In the UK it is unusual to get a well defined wedge as shown, becouse the birds in a passerine movement seldom travel at the same average speed and on a common heading, unless there is a high tail wind.

It has been suggested that variations in echo intensity produced by MTI operation can be calibrated out by switching the MTI off when watching a bird movement and then referring the 8-point intensity scale obtained with MTI "on" to this MTI "off" recording. Apart from severe practical difficulties in making this comparison the results will be invalid on technical grounds. Without MTI the radar and its processing are recording echo intensity which is proportional to target echoing area, but with MTI the radar is recording intensity which is proportional to echoing ara and also to the radial velocity component of the target. Except in special cases it will be difficult to obtain sufficient information on the radial velocity components of a large scale movement to correct the "calibration".

3. Bird Surveillance and ATC Cpmpatibility

A common problem that occurs when a radar is employed for watching bird movements is that a lot of data is lost due to radar or photographic faults, or because records are spoilt by the presence of unwanted "weather" echoes, or because the radar parameters have been changed during routine ATC operations. A Canadian team relates that in a 239 day operation in 1964-65 nearly 30% of the morning films and 29% of the evening films were lost due to radar settings, radar maintenance or unknown causes (1). The same team spent 896 hours on night operations in 1969 and 26% of the film was lost because of radar setting faults, camera faults, radar maintenance and unknown causes and 14% of the film was unassessable, because of "weather" clutter or the operator used special techniques to eliminate undesired echoes, including birds (2).

The Canadian experience is not unique, it is commonly shared by many workers using a radar on a part-time basis, when the radar's prime purpose is for ATC or defence. The wise solution to this problem is to get rid of the part-time atmosphere by integrating the radar surveillance of bird movements into the general ATC surveillance plan and at the same time to make improvements to the radar and the intensity recording system.

I have indicated that parameters in the PPI-photography/photographic processing chain are extremely difficult to control and optimize, and that interpretating the PPI intensity scale is far too arbitrary a task for serious operational use in a situation where the work load of the air traffic control staff, even with computer assistance, is soaring.

The PPI-photographic method with its PPI setting, photographic processing and camera faults, and the radar parameter changes imposed by ATC operations can be circumnavigated by using a separate receiver-recording chain that can be fed out on to a magnetic tape recorder. The receiver recording system can be fitted in parallel with the existing receiver-PPI chain to almost any type of ATC radar. It is a system that enables the radar to be used for both ATC and bird movement purposes at the same time without one interfering with the other.

4. The Bird Echo Intensity Measuring Receiver

The existing radar receiver - PPI chain is used for qualitative information on the broad scale movement of birds and the whereabouts of "weather" clutter. An additional receiver channel is used for the quantitative measurement of bird echo intensity. The bird intensity measuring receiver can be fitted with a direct calibration facility to set-up the 8-point intensity scale. The measuring system can measure a range of intensities of up to 9odB in terms of an accurately specified law, whereas the PPI-photographic method is confined to a range of 1o-2odB and an ill-defined law subject to setting and processing changes.

A block diagram of an ATC radar fitted with a non-MTI receiver channel and a MTI receiver channel is shown in Fig. 3. The bird echo intensity measuring receiver the third channel on the extreme left. In many cases it will be satisfactory to take the output of the headamplifier as shown from the by-pass point, but if a microwave amplifier is available it may be advisable to by-pass from the amplifiers output port. The intensity receiver consists of an IF bandpass filter for defining the receiver bandwidth, a logarithmic receiver of true law and 9odB input/output range, a means of "gating" bird echoes in range and bearing, a sample and hold circuit for prolonging the short duration of the received echo pulse and a low-pass filter to remove unwanted parts of the receiver spectrum. The intensity data from the receiver is fed onto a magnetic tape recorder. Besides recording intensity it is necessary to record range and bearing "gate" data. The box marked "state of radar indicator" permits the recording of additional data, such as whether linear or circular polarisation is being used, and it cuts out the uncertainty of written records.

The general principles used in the intensity measuring receiver system have been used to measure ground clutter echoes at London Airport using one of the airport's ATC radars (3), and they have been used elsewhere to measure bird echoes. The operation of the receiver can be explained by means of Fig. 4. A range and bearing "gate" indicated at R is laid onto the bird movement shown on the PPI. The "gate" is brightened up to show its position, but the "gate" marker does not need to be retained on the PPI except for putting-on purposes. The bird movement, heading north in this case, moves continuously through the "gate". The intensities of the echoes passing through "gate" are recorded at their correct bearings shown on the right-hand diagrams. Echo intensities are recorded each time the serial scans through the "gate" position. As time passes the intensity pattern changes as shown by the patterns taken every half hour. It is possible to leave the "gate" position fixed once it has been positioned on the "centre of gravity" of the main bird movement. The "gate" is positioned clear of ground anf weather clutter in order to avoid collecting unwanted data.

The intensity and position data is encoded onto a magnetic tape, which can be docoded, when and as required, using a computer programmed to print-out the bird echo intensity chart shown in Fig. 5. Echo intensities, bearing angles and times correspond to the data in Fig. 4. The changes of intensity taken from a nocturnal migratory bird movement over the bearing sector 25.5. to 57.5 degrees are shown in the map of Fig. 6 at equal 3o minute intervals. Intensity levels above -31dB of radar cross section of 1 sq metre have been outlined. Such a decision can be programmed into the computer and printed out, and in a similar way so can a warning level.

The intensity measuring receiver is calibrated by feeding a microwave signal, controlled by an attenuator, into the microwave mixer. This adjustable signal, referenced to a calibrated noise tube, is used to calibrate the receiver. The radar and receiver channel can be calibrated in absolute terms by flying a (balloon-borne) known metal sphere. The intensity levels can then be referred to this echoing cross-section or to an arbitrary 8-point scale reference to the noise tube. Unlike the PPI-photographic intensity method it is easy to calibrate this receiver to specified levels and repeat the calibration year after year. The calibration is made before each operation and recorded.

References:

1)	Blokpoel, H.	"A Further Attempt to Forecast Bird Migration over Cold Lake, Alberta", Field Note No 54, N R C., Ottawa, Canada, October, 197o.

2) Blokpoel, H & Desfosses P.P. "Radar Observations of Local Bird Movements near Calgary, Alberta", Field Note No 53, N R C, Ottawa, Canada, October, 1970.

3) Warden, M.P. and Wyndham, B.A. "Ground Clutter Measurements at London Airport (Heathrow)", RRE Memorandum No 2606, May, 1970.

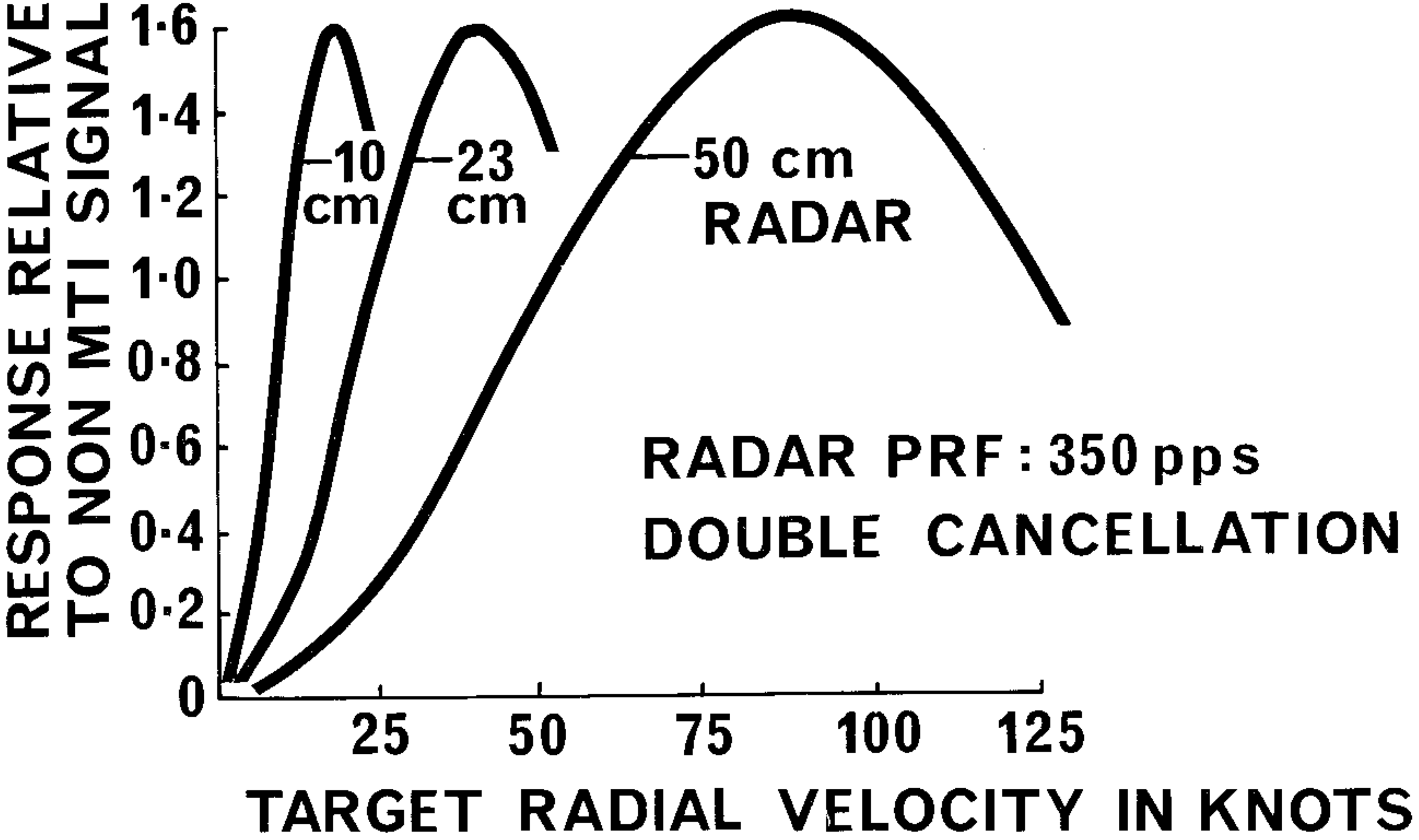
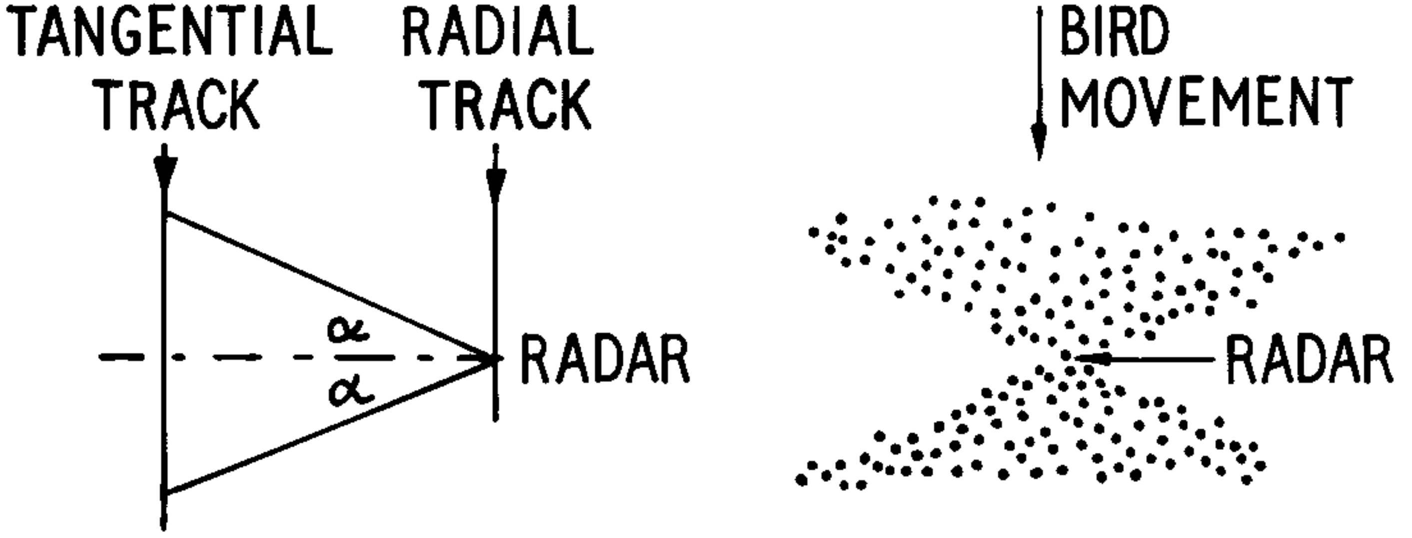


Fig. 1
MTI VELOCITY RESPONSE CURVES



MTI WEDGE ON
PPI FOR UNIFORM VELOCITY

FIG. 2

RADIAL AND TANGENTIAL VELOCITIES

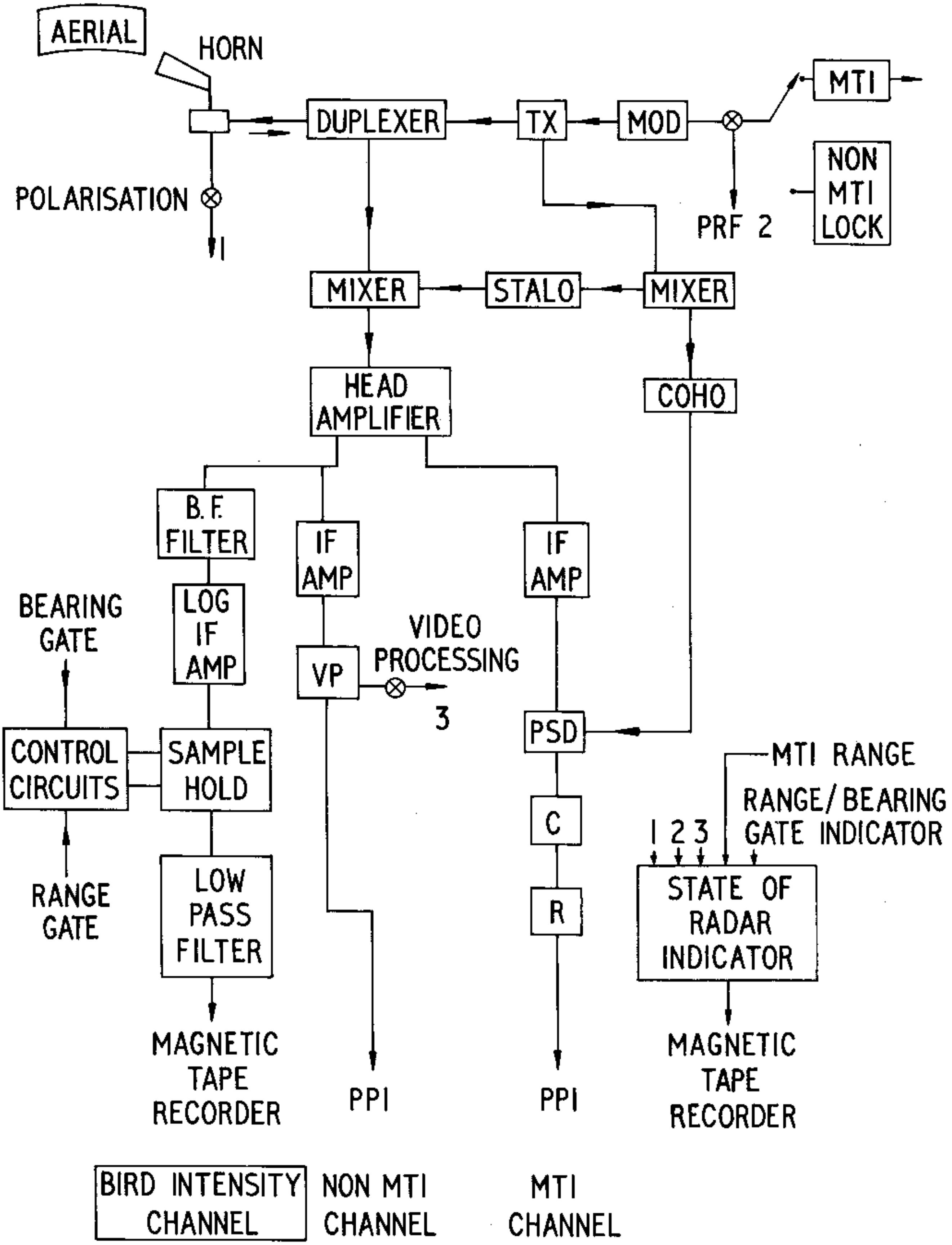


FIG. 3

ATC RADAR WITH INTENSITY MEASURING RECEIVER

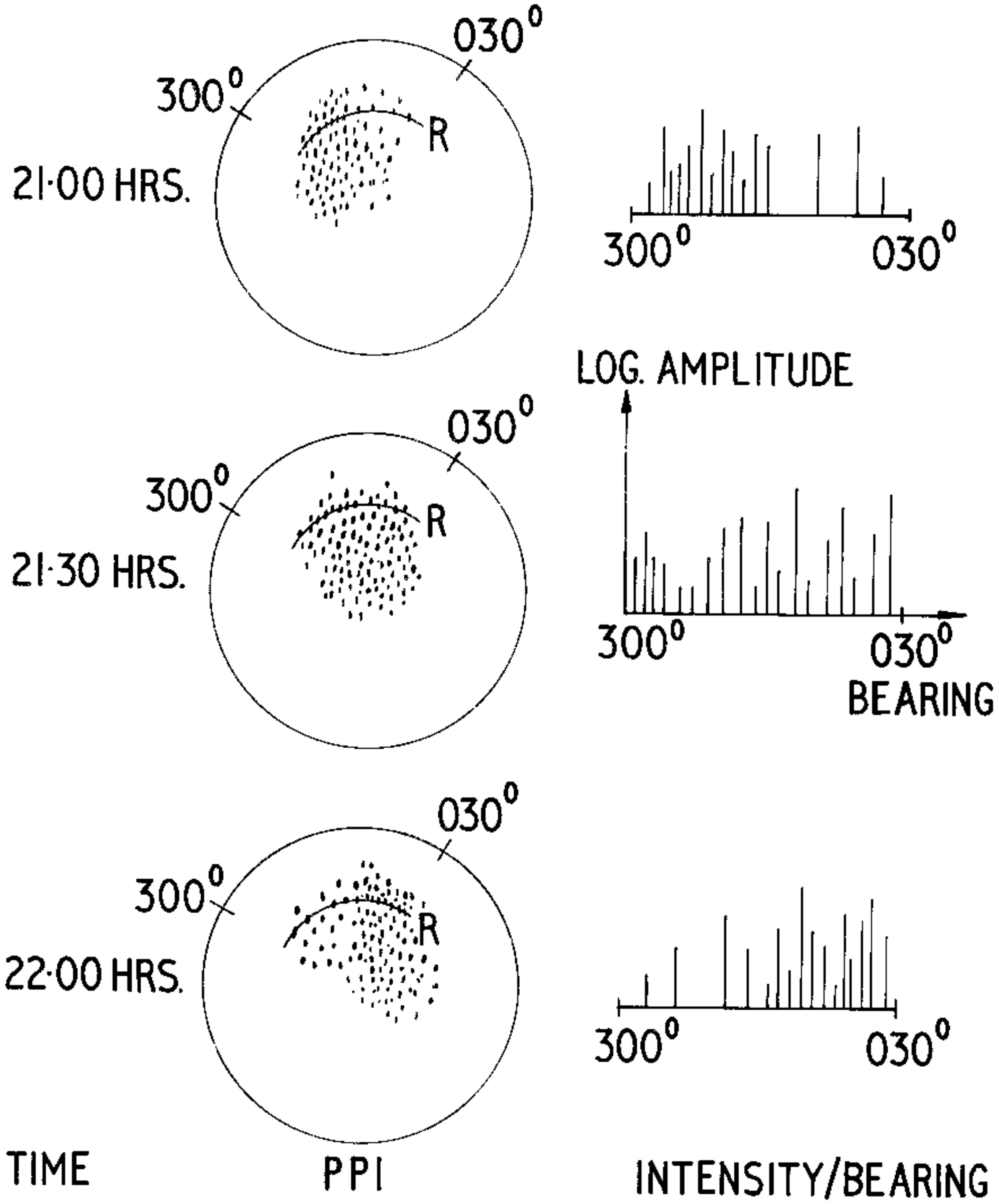


FIG. 4

PPI GATE INDICATOR AND INTENSITY/BEARING DIAGRAMS

DATE: 27:10:69 RANGE: 21n miles

TIME (HOURS) →

BEARING ANGLE (DEGREE) ↓	21·00	21·30	22·00
300	−30	−26	−36
310	−28	−28	−28
320	−36	−29	−33
330	−27	−36	−32
340	−25	−25	−23
350	−30	−28	−25
360	−36	−30	−28
010	−30	−25	−30
020	−25	−30	−28
030	−26	−36	−25

Numbers in rectangles are intensity in decibels. – 36dB is peak noise.

FIG. 5
BIRD INTENSITY CHART