551.508.85 .822 : 551.557

A method of using the Radar AA No. 3 MK III to track the F-type radio-meteorograph to obtain both radiosonde and upper wind data

B. K. GUPTA and S. P. VENKITESHWARAN

Meteorological Office, Poona

(*Received 14 February 1952*)

ABSTRACT. The paper describes a method of adapting the radar AA No. 3 MK III operating on 204 mcs to track F-type radiosonde signallers on this frequency and thus obtain in addition to radiosonde data, information about upper winds also at levels higher than what is possible with the radar tracking a dipole passive target. The details of construction of the signaller on 204 mcs and the radiosonde recording equipment are briefly described. The advantages of this type of adaptation in meteorological technique is indicated.

1. The radar equipment

The India Meteorological Department obtained a few radars—AA No. 3 MK III—for measurement of upper winds during cloudy weather (Fig. 1). Some of the specifications of this radar are—

Frequency	.. 204 mcs (wave length 1·5 metre)
Pulse recurrence frequency	.. 1000 cs
Pulse width	.. 1 microsecond
Peak power	.. 90 kw
Presentation	.. Type A with strobing device
Accuracy	.. ± 1° in angle between 20 to 70° for elevation and ± 100 yards in range
Range	.. Upto 16,000 yards
Antenna	.. Transmitting antenna is a single Yagi array with a folded dipole as an active element backed by a mesh reflector. Receiving antenna consists of four Yagi arrays mounted at the four corners of a square, with one of its diagonals in the vertical plane for elevation angles and the other for azimuth angles.

This radar is in regular use at Poona since 1949 for obtaining upper wind information, by tracking passive targets. As the wave-length of the radar is 1·5 metres, dipole targets are used. They are made out of three lengths of bare copper wires (18 S.W.G.), each of 27·5 inches in length, soldered in their middle at right angles to each other and fixed in a light bamboo frame. This type of target is simple to make and is also very light weighing only about 150 gm. Due to this, it is possible to use smaller size balloons to lift the target or to increase the free lift of the balloon to keep the target at fairly high angles to avoid " clutter " effects on the radar which appears when the target is at low angles at great distances.

When radar observations were first started in June 1949 at Poona, the target was attached to the F-type radiosonde balloon (1948) released at 1400 GMT and the rate of ascent was about 20 km hr^{-1}. But during the monsoon months June to August, the winds in the lower levels at Poona are from the west up to nearly 6 km and blow at approximately 30 km hr^{-1} in some levels. The balloons were, therefore, found to drift to low angles before they had reached any appreciable height and the radar echoes used to get lost in the ground clutter. To obtain upper wind information to greater heights, the rate of ascent of the balloon had to be increased to nearly 30 km hr^{-1}. The high rate of ascent, however, could not be employed with the radio meteorographs, and therefore the practice of following targets attached to radiosonde balloons was given up and separate balloons were used to carry the light targets only. The balloons weighed about 350 gm and were given a free lift of 2000 gm. A summary of the upper winds obtained at Poona with the radar up to a height of about 13 km during the monsoon months in the two years 1949 and 1950 have already been published (Venkiteshwaran and Yegnanarayanan 1951).

2. Adapting the radar to track active targets

For obtaining upper winds with the radar AA No. 3, MK III up to a height of about 12 km separate ascents with fairly big sized balloons and high free lift will have to be adopted even with the light dipole passive targets mentioned above, not only during the monsoon months in Peninsular India, where the winds are strong westerly in the lower levels, but also in northern India during winter where also the winds are strong westerly.

Again, with this type of radar, it is possible to obtain upper wind information only up to a height of about 12 to 14 km under the best conditions. It was, therefore, examined whether the radar can be adapted to follow the F-type radio-meteorograph itself, if it is operated with a signaller on the same wavelength as that of the radar, *viz.*, 204 mcs. In this case, the transmitting portion of the radar will not operate. The signals received from the radiosonde signaller will naturally be very much stronger than that from the dipole target scattering the energy from the radar transmitter. It can, therefore, be followed to much greater distances. Normally, when using the radar, the passive dipole target has to be followed through a telescope for centering the spot in the angle units till the target has moved to a distance of more than 1000 yards and the transmitted and received pips separate on the cathode ray tube for range. With the radiosonde signaller, the centering can be done from the instant the balloon is released.

When the radiosonde signaller is tracked with the receiving portion of the radar, it should be possible to obtain a record of the radiosonde signals with the usual F-type radiosonde recorder after some simple modifications. The radiosonde signals, together with the readings of the elevation and azimuth angles of the signaller every minute, will give both the radiosonde data and upper wind information. When the radar is working normally the height of the balloon is computed from the range and elevation angles. When tracking the radiosonde signaller, the height will have to be obtained from the values of pressure and temperature.

Normally the radar requires three people to operate it, one for the range, a second for the elevation and a third for the azimuth. However, the practice at Poona has been to have one person to operate the range and another for both the elevation and azimuth controls. A third person was necessary only for the first few minutes to keep the balloon in the field of view of the telescope fixed on the aerials till the transmitted and received pulses separated on the range oscilloscope.

Three persons including an observatory attendant are necessary to operate the F-type radiosonde. A total of five persons will be necessary for operating the radiosonde and radar simultaneously. If, however, the radar receiver can track the radiosonde signaller, both pressure, temperature, humidity and winds in the upper air can be obtained with three persons.

The method of obtaining information about pressure, temperature, humidity and winds in the upper air from the signals from radiosonde transmitter has been practiced in America (Kirkman and Lebedda 1948). Here the radiosonde transmitter operating on a frequency of 400 mcs is tracked with the Rawin equipment SCR-658. To obtain the humidity, pressure and temperature data, the output of the frequency modulated channel of the Rawin receiver is fed to the external radiosonde recording equipment where the results are recorded on a moving paper chart.

The two units, *viz.*, the SCR-658 and the radiosonde ground equipment are independent units. However, if information about upper wind alone is required, it can be obtained only by letting off with a balloon a wireless transmitter operating at least a pressure switch to obtain the height of the balloon at different instants when azimuth and elevation angles are noted. This method is more costly and difficult than by following with the radar a simple and light dipole target made out of three pieces of 18 S.W.G. copper wire let off with a small size balloon.

By the method described in this paper, the radar can follow and record the radiosonde signals and it will, therefore, be possible to obtain both the radiosonde and upper wind data. At the same time, when only upper wind information is required, the equipment can be used as a radar. The super-heterodyne radar receiver can replace the super-regenerative radiosonde receiver, and therefore only the radiosonde recorder has to be suitably coupled to the radar receiver.

The method of constructing the wireless signaller for use with the radio-meteorograph so that it can be tracked with the radar receiver and the details of the radiosonde recorder equipment are described below.

3. Signallers for use with F-type radio-meteorographs for following with the radar

The feasibility of using the radar receiver to follow the radio-meteorograph signaller depends upon the construction of a suitable radiosonde transmitter working on 204 mcs. This was effected by altering suitably the signallers used with the American Rawin equipment SCR-658. The specifications of these signallers are given below—

Frequency	400 mcs
Oscillator valve	Type 955
Plates voltage	108 V
Filament voltage	6 V
Grid voltage	36 V

Fig. 2 (*a*) shows the diagram of connection and Fig 2(*b*) is an exploded view of one of the transmitters adapted to operate on 204 mcs for use with the radio-meteorograph to be tracked with the radar. The original signaller on 400 mcs was modified as follows—

(*a*) The grid and anode Lecher wires were extended by 5½ inches with 16 S.W.G. bare copper wires. These wires were bent suitably to minimise the overall size of the signaller.

(*b*) To minimise the drain on the H.T. battery, the anode current was reduced by increasing the grid resistance from 1500 ohms to 20,000 ohms.

(*c*) A small R.F. choke is used in the H.T. line to prevent any R.F. oscillations reaching the battery. A 0·0005 mfd. mica condenser across the meteorograph connections prevents sparking at the contacts in the meteorograph affecting the oscillator.

(*d*) The aerial used with the original signaller (17 S.W.G. wire, 13 inches long) is extended to 28 inches by soldering another piece of copper wire.

(*e*) The H.T. and L.T. for the original signaller was obtained from specially constructed lead cells manufactured for this purpose in America. As such cells cannot be obtained now in India, about 60 unit cells of the type used with the F-type radio-meteorograph were assembled to get on load about 80 volts for the H.T. These cells were assembled in a separate cardboard box along with 5 unit cells (Eveready No. 935) for the filament voltage. The plate current is about 10 to 15 ma. during oscillations. The grid bias of +35 to +40 was tapped from the H.T. source. The weight of this whole unit is about 600 gm and compares favourably with the special lead cells manufactured for this purpose in America weighing about 700 gm.

(*f*) The oscillator is placed in a wooden box of size 7½″ × 3¼″ × 3¼″ with the cardboard box containing the batteries above it, and the aerial hanging below. (Fig. 2 c).

(*g*) The R.F. power output of the modified signaller is about 150 milliwatt. Its overall efficiency is about 30%. The signallers had been tested in the laboratory for two hours continuously. No appreciable instability in their performance was noticed due to limited

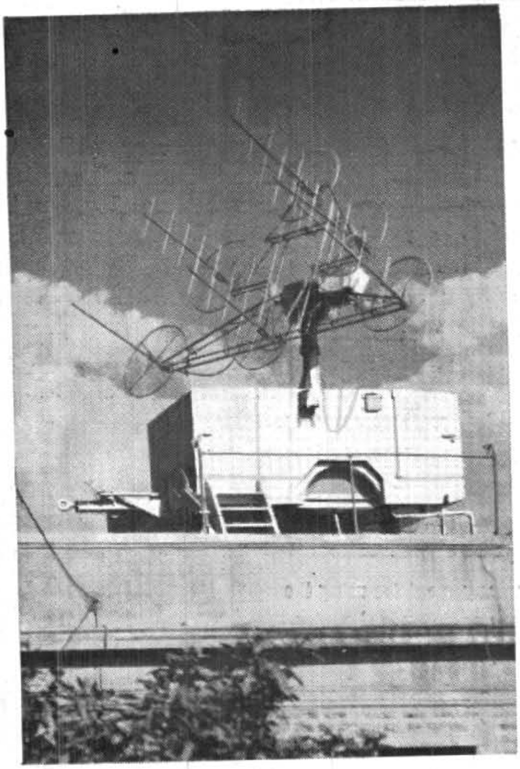

Fig. 1

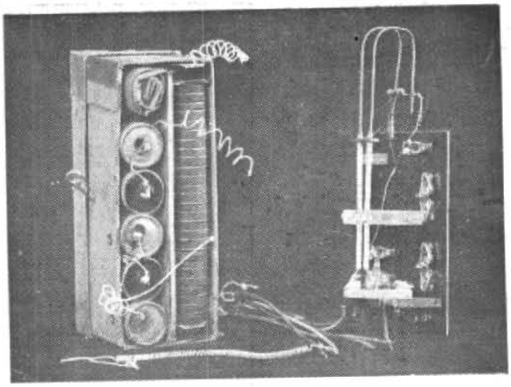

Fig. 2 (b)

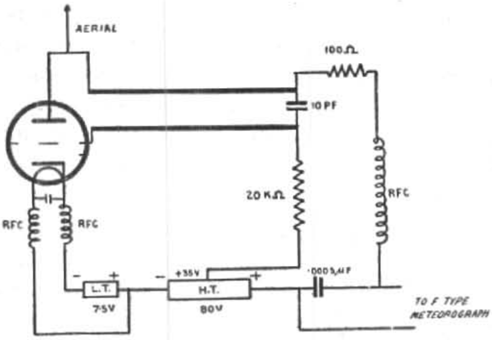

Fig. 2 (a). Oscillator producing 204 MC/S

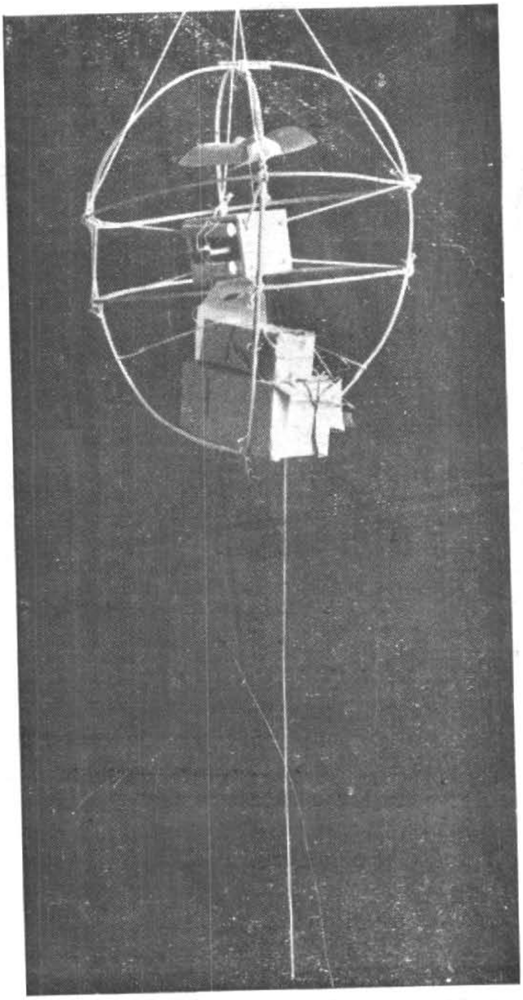

Fig. 2 (c)

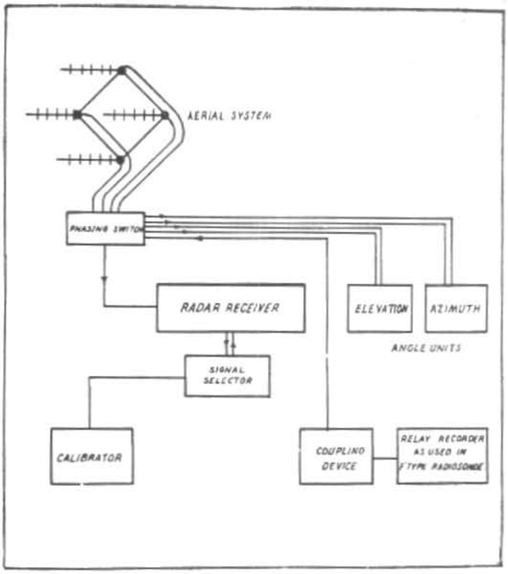

Fig. 3. Block diagram of arrangement for using the radar receiver to track the radiosonde signaller

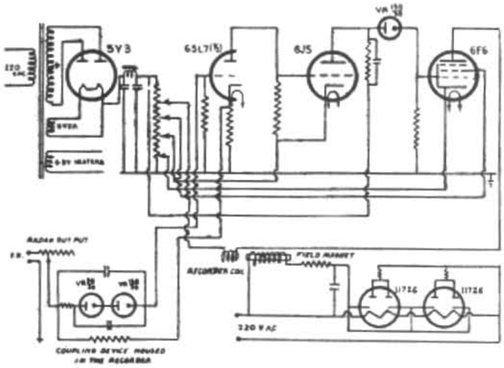

Fig. 4. Connections for radiosonde recorder fo coupling to the radar receiver

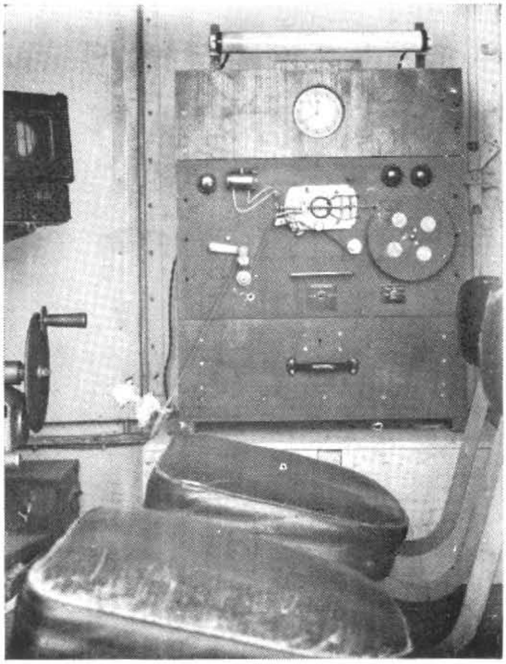

Fig. 5

anode or filament voltage changes. But during actual flights there were slight frequency drifts mainly due to temperature changes experienced in the atmosphere. There was, however, no difficulty in handling this drift with the radar receiver.

4. Modifications in the radar receiver for using it with the radiosonde recorder

For tracking the signaller on 204 mcs coupled to the radio-meteorograph, only the receiver unit with its four aerials and phasing switch, the signal selector, range calibrator and the angle units are used. The transmitter and the automatic range unit of the radar are not necessary.

The receiver is a super-heterodyne set with two R.F. stages, four I.F. stages followed by video and peak rectifier stages ; it has also an arrangement for gating at the end of the video stage. The angle units are fed from the output of the peak rectifier. Normally on C.W. or I.C.W., no signals will pass beyond the second detector stage, and it is necessary to modulate the signal at or near 1000 cs to get the angle sensitivity. This is obtained by the jamming location device provided in the receiver. With this device, a bias of —80 volts can be applied to the first two I.F. stages in the receiver, thereby making these valves insensitive to the incoming signals. At the same time, the strobe pulse generated in the signal selector unit by the calibrator, which is at about +80 volts, a frequency of 1000 cs and a duration of 6 microseconds is fed to the suppressor grids of the I.F. valves already biased to—80 volts. Thus when the strobe pulse is on, the signal will pass through the I.F. stages and as the frequency of repetition of the strobe pulse is 1000 cs the receiver angle units behave as they do in the normal radar operation. Thus when the jamming location device is brought into operation, the radar is ready for tracking active targets, and can, therefore, track the signaller on 204 mcs attached to the F-type radio-meteorograph. The elevation and azimuth of the signaller can be known by keeping the spots in the centre of the cathode ray tubes in the angle units. Fig. 3 is a block diagram of the arrangement for using the receiver in the radar for tracking the radiosonde signaller. Fig. 4 shows the details of electronic circuit in the radiosonde recorder and the method of coupling the radar receiver to it.

For tracking the active target with the radar, the calibrator is kept continuously on and the strobe pulse set between two calibration pips. The jamming location switch in the receiver should also be on and the gain control adjusted till the strobing pulse is about half an inch in size. The receiver can be tuned to the signal from the radio-meteorograph with the oscillator tuning condenser on the radar receiver as usual. When the signal is received, the broad patch on the angle units will become a sharp line or spot depending on the previous setting of the oscilloscopes. Signal and no signal can be distinguished on the signal selector unit also by the strobe pulse becoming short or long.

The signals from the F-type radiosonde are intermittent and occur with a frequency of about 10 to 20 per second, and the spot on the angle units will, therefore, be vibrating in size. But there will be a signal of comparatively longer duration during the contacts of the pressure, D.B., W.B. and fix reference points with the silver spiral. Usually a complete cycle is performed in about 2 minutes and during this period there will be 5 long period signals during which the receiving aerials can be adjusted for both elevation and azimuth by keeping the spots on the respective cathode ray tubes in the centre.

5. The recording equipment for the radiosonde signals

The output from the peak rectifier in the radar receiver feeds the angle display units through the phasing switch. In following the radiosonde signaller, a portion of the output from the peak rectifier is fed to the F-type recording unit (Fig. 5). The recording unit is fitted in the radar housing, near the angle units, so that two observers or even one can manipulate the equipment. This radiosonde recording unit can be easily disconnected from the radar receiver when the radar has to be used for following passive targets.

The radiosonde recorder is described briefly below.

In the centre of the recorder panel (Fig 5) is mounted an electro-magnet with the moving coil and recorder assembly. A spool of paper tape is mounted on the right and the tape pulling rollers on the left.

The recorder coil is wound on a tufnol former and moves freely in an annular space in the electro-magnet. The moving coil is fixed on an arm, with a vertical pivot at one end and a capillary tube fed with ink at the other for writing on a moving paper tape.

There is another arm fixed on a vertical pivot. This arm also carries a capillary tube at one end for recording on the paper tape, but the other end of the arm is linked to a lever which is moved once in 15 seconds by a cam on the speed reduction train of worms and gears on the tape pulling motor.

The tape pulling arrangement consists of a 1/20 H. P motor (capacitor type, 220 volts A.C., 50 cycles, 1440 r.p.m.) coupled to a gear train, with the final shaft projecting into the panel. This shaft is fitted with a rubber tube. A knurled roller is kept pressed on this shaft by a spring ; these two rollers move the paper tape between them with a speed of about 4 ft min^{-1}.

Nearly 20 flights were made in clear weather with the radio-meteorograph operating a signaller on 204 mcs and they were followed simultaneously with the radar and a theodolite. With the exception of a few, all the flights could be followed till the balloon burst. There was good agreement also between the values of winds obtained by the two methods.

Simultaneous radiosonde ascents were also made with one meteorograph operating a signaller on 204 mcs and the other on 75 mcs : the signals from the former were recorded on the radar and those from the other with the usual radiosonde ground equipment. It was observed that upper air data were obtained with the radar up to as high a level as with the other instruments and sometimes even to a higher level. Even when the signals were weak for obtaining radiosonde records the signaller could be tracked with the angle units for a longer time.

6. Conclusion

Radars operating on a frequency of 204 mcs or less have become obsolete now and are no longer being manufactured. These have all been replaced with those on centimetre waves. If simple and light signallers operating on centimetre waves can be constructed and sent up with the radio-meteorographs, centimetre radars can also probably be used to track them.

Attempts were being made in America in designing a radio set, AN/GRD-1 (Kirkman and Lebedda 1948) operating on a frequency of 1725 megacycles capable of even automatically tracking the targets. But they are designed only for use with active targets. When upper wind information is required frequently during the day at a number of places, the radar capable of tracking a passive target will be cheaper and simpler. Therefore radars capable of tracking, as required active or passive targets sent up with balloons summarised in this paper, appear to have certain additional advantages in meteorological technique.

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