

THE EFFECT OF OPERATIONS ON THE GROUND NOISE FOOTPRINTS

ASSOCIATED WITH A LARGE MULTIBLADED,

NONBANGING HELICOPTER

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INTRODUCTION

Pending noise certification of helicopters has focused attention on the effects of their operations on ground noise exposure. Knowledge of the effects of helicopter configurations (blade numbers, airfoil configuration, etc.) and operations plays an important role in the evolution of final procedures to be utilized for the noise certification of helicopters. In addition, as noted in reference 1, the prediction of realistic and representative ground noise contours, or footprints, caused by various aircraft operations, including helicopters, can aid significantly in minimizing the noise intrusion.

Considerable effort has been expended in an attempt to better understand helicopter operational effects so that improved noise prediction techniques can be developed (ref. 2). Measurements made to date are providing a better understanding of the physical phenomenon involved. However, the results from single point measurement programs suggest that the determination of true ground exposure necessitates the use of numerous ground noise measurements at multiple locations along, and perpendicular to, the aircraft ground track. The recently developed remotely operated multiple array acoustics range (ROMAAR) at NASA Wallops Flight Center, reference 3, was designed to provide an arrangement for obtaining noise measurements along the aircraft ground track and at various lateral positions simultaneously along with information on aircraft position, operating parameters, and local meteorological information.

In order to expand the data base of helicopter external noise characteristics, NASA conducted a flyover noise measurement program utilizing the NASA Civil Helicopter Research Aircraft. In these studies, both the ROMAAR and a 2560-m linear microphone array, laid out along a runway at NASA Wallops Flight Center, were utilized for the purpose of documenting the noise characteristics of the test helicopter during flyby and landing operations. By utilizing both the ROMAAR concept and the linear array, the data necessary to plot the ground noise footprints and noise radiation patterns were obtained.

The purpose of this paper is to present examples of the measured noise signature of the test helicopter, the ground noise footprint or contours, and the directivity patterns measured during level flyby and landing operations of a large, multibladed, nonbanging helicopter, the CH-53.

APPARATUS AND METHODS

Test Site

The NASA Wallops Flight Center on the Eastern Shore of Virginia was chosen as the test site of these acoustics tests. The sketch of figure 1 indicates the geographical relationship between the Wallops Flight Center and the Langley Research Center. The insert in the figure, an aerial photograph of the airfield at Wallops Flight Center, gives an indication of the general runway layout and the type of terrain surrounding the test area.

The Wallops Flight Center offers a number of desirable characteristics that are necessary for flyover noise testing. The ROMAAR (ref. 3) is located at the Wallops Flight Center and was made available for this series of acoustics tests. The ROMAAR is located in an area south of the airfield where ambient noise is low and where aircraft other than the one under test do not operate routinely. The microphone array is located in relatively flat, open areas which tend to minimize shielding, reflection, and shadow-zones, etc. The range is supported by aircraft tracking and weather observation facilities.

The general ROMAAR and linear-array concept combines the basic elements of flyover noise testing, which include acoustic measurements, aircraft position measurements, and weather measurements. The noise measurement elements of the range consist of analog stations (manned) and/or digital stations (unmanned). For these tests, aircraft positions over the range and over the linear microphone array were determined by radar, and the aircraft operating parameters were read from the standard instrument panel aboard the test aircraft. Data from all of the above sources were time correlated using a time signal generated by WWVB.

Test Helicopter

The test aircraft for this series of noise experiments was a modified CH-53A turbine-powered transport helicopter that is being utilized as a test bed in the NASA Civil Helicopter Technology Program. The test helicopter has uprated engines and drive systems and has a normal gross weight of 16 330 kg (the uprated engines and drive system make this machine comparable to the later D model). The test aircraft has also been outfitted with a 16 seat passenger compartment for ride quality research. A photograph of the helicopter utilized for these tests is shown at the top of figure 2. The general dimensions of the CH-53 are shown in the drawing at the bottom of the figure. Briefly, the main rotor has six blades and has a 22-m diameter, and the tail rotor contains four blades and is 4.9 m in diameter.

Aircraft Operations

ROMAAR.- As indicated by the schematic drawings of figures 3(a) and (b), landing and level flyby operations were performed over the ROMAAR. The ROMAAR consisted of 38 measurement positions which were located to the south of runway 04 and covered an area approximately 500 m to either side of the extended centerline of runway 04 and approximately 10 km downrange. The circles in the sketches indicate the approximate deployment of the microphones.

For the landing approach measurements, the aircraft approached the range at an altitude of approximately 457 m until the six-degree glide slope was intercepted; at that point a descent was made to a full stop landing at a point approximately 40 m inside the approach end of runway 04/22. For these operations the approach was always made from the south, directly over the ROMAAR.

For the level flyby noise measurements, constant altitude flyovers were made along the extended centerline of runway 04/22, directly over the ROMAAR. The helicopter was flown at a nominal altitude of approximately 152 m at an airspeed of 49 m/s. For this particular series of tests, the helicopter was flown on reciprocal headings over the ROMAAR. The helicopter flight path and power conditions were stable approximately 1 km prior to range entry and 1 km after leaving the range.

During these operations, the spatial position of the test aircraft was determined by utilizing a precision radar; the general specifications are listed in reference 3. For both the landing approach operations and the level flyby operations over the ROMAAR range, the onboard flight parameters were read from pilot display instruments.

Linear microphone array.- As indicated in figure 3(c), a linear microphone array was established along the centerline of runway 04/22. Utilizing the standard analog measurement systems, microphone positions were established at distances indicated in the sketch. For this series of flights, the flight track was established perpendicular to the array and overhead of the center microphone. Flights were made on reciprocal headings at airspeeds of 47 and 82 m/s and at altitudes of 76 and 152 m. For this series of tests, the aircraft was in stabilized condition approximately 1 km before passing over the microphone array and these conditions were maintained approximately 1 km after passing overhead.

Shown in figures 4(a) to (c) are radar data concerning the altitude, lateral displacement, and velocity time histories associated with the flight operations over ROMAAR for the six-degree approach and level flight conditions and for level flight operations over the linear array. It can be noted from these figures that slight variations in altitude, lateral displacement, and velocity existed from flight to flight. These variations in the flight path and velocity could have resulted in some minor variations in the noise level values from flight to flight. Corrections can be made for these variations; however, in this case they were felt to be so small that no attempt was made to include such corrections for the data of this paper.

METEROLOGICAL CONDITIONS

Shown in figures 5(a) and (b) are the measured variations in selected meteorological quantities for the two time periods during which the subject tests were conducted. Temperature, relative humidity, wind direction, and wind speed are plotted as functions of altitude. The hatched region represents the ranges and measured values at altitudes up to and beyond the test altitudes. These data were obtained by means of standard rawinsondes. Data concerning altitude, temperature, and relative humidity are telemetered to a receiver on the ground, and dual theodolites are used to track the lifting balloon in order to obtain the wind information. Alternating temperature and humidity sondes were released at approximately 1/2-hour intervals throughout the test period. These data are presented for information only and no corrections have been made to the measured noise data of this paper to reference day conditions.

TEST RESULTS

Noise Characteristics

Typical noise characteristics of the test helicopter during a level fly-over operation at an airspeed of 49 m/s and an altitude of 152 m are illustrated in figure 6. Presented in the left-hand portion of the figure is a sound pressure level time history measured on the ground track directly under the test aircraft. The time of overhead passage of the helicopter is noted on the figure, and it can be seen that for this particular helicopter the maximum sound pressure level occurs at approximately overhead passage. A frequency spectrum of the noise at the time of maximum sound pressure level is shown in the right-hand portion of the figures. It can be seen that the spectrum is dominated by the relatively low frequency components associated with the main- and tail-rotor blade rotational noise. For all of the measurements made at the analog station, data of the type illustrated in figure 6 are available. For the digital stations, the dB(A) descriptor was selected for the purpose of reporting and dB(A) time histories are available from each of these measurement stations.

Noise Level Variability

The data of figures 7, 8, and 9 are included to indicate the data spread and variability experienced for this series of tests. An indication of the noise variability can be obtained by examining the histograms of figures 7 and 8. Shown in these figures are histograms which indicate the variations in maximum dB(A) for six flights of the test aircraft over the 2560-m linear array at an altitude of 152 m and an airspeed of 49 m/s and during an approach operation over the ROMAAR. Data are grouped in intervals of 5 dB(A). In general, these figures indicate that less scatter is associated with stations located under the aircraft, along the flight track than at the lateral locations. As distance increases and/or as look angle β decreases, the variability in the noise measurements increases.

Presented in figure 9 are average data from four passes of the test helicopter over the ROMAAR at an altitude of 152 m and an airspeed of approximately

49 m/s. The data, presented at the top of the figure, are for the on-track microphones only. The average levels from these microphones are shown as functions of position on the track; as an aid to interpretation, a line has been drawn at a nominal level of 80 dB(A). It is interesting to note that, over the entire 10-km length of the ROMAAR, the on-track variations are on the order of approximately 3 dB(A).

Utilizing the average dB(A) levels from all measurement stations in the ROMAAR array for the same four level flybys, data are presented in the lower portion of figure 9 which indicate the extent of the ground noise footprint of the helicopter. For each measurement station, the average dB(A) level for the four flights is shown at the measurement station location. Based on these average levels, the 75-dB(A) and 70-dB(A) noise contours, or footprints, were developed. These contours were obtained by appropriate cross-plotting and extrapolation of the average values of the measured noise level parallel to and perpendicular to the aircraft ground track. Inspection of the contour indicates that the pattern is quite symmetrical in nature around the aircraft ground track.

Ground Noise Contour and Directivity Patterns

Six-degree landing approach operations.- The ground noise contours for a six-degree landing approach of the test helicopter are shown in figure 10. These contours were constructed utilizing the average of the maximum dB(A) levels measured at each of the 38 ground noise measurement stations during five 6° landing operations over the ROMAAR. Again, these contours were constructed by cross-plotting and extrapolation of the average of the values of the measured levels parallel and perpendicular to the aircraft ground track. Again, it should be noted that the ordinate and abscissa are plotted to the same scale. One can see that during the approach the contours are parallel to the flight track and are symmetrical in nature. As the helicopter begins its descent other contours appear and, due to the descending flight, these contours close. These closed contours are also symmetrical about the flight track which suggests that this particular helicopter does not exhibit any sharply directional noise pattern.

Further insight into the noise radiation patterns for the test helicopter can be obtained by examining the results from the level flybys over the linear microphone array.

Level flybys.- The data of figure 11 represent aircraft noise directivity patterns obtained as a result of analyzing the noise data for six passes of the test aircraft over the linear microphone array. The aircraft was frozen overhead of the center microphone of the linear array and at several locations during the approach to and the departure from the array. The aircraft was frozen at five-second intervals along the flight track, and the dB(A) levels were read from the time histories at each measurement location for that particular time. In this manner a grid of dB(A) values was established for each pass. These data were then extrapolated and cross-plotted; one could then choose a particular dB(A) value and a constant dB(A) contour or line drawn through the intercept points. The data of figure 11 show that the radiation pattern is

symmetrical about the flight path axis; however, the levels seem to be somewhat higher to either side of the aircraft than those to the front and rear of the aircraft. These data graphically illustrate the symmetrical patterns that were suggested by the previous figure.

The variation in the directivity patterns for the test helicopter as a function of altitude and airspeed are illustrated in figure 12. It can be seen that increasing altitude results in very small changes in the shape or size of the radiation patterns. This suggests that a uniform radiation pattern exists below the helicopter. On the other hand radiation patterns developed from data measured at the same altitude but at two airspeeds show an increase in the radiation pattern size in addition to a change in shape. The increase in level is thought to be due to the increase in disc loading at the higher speeds, while the shape is thought to be modified by a change in the tilt to the blade tip path.

CONCLUDING REMARKS

A field measurement program was conducted utilizing the NASA Civil Helicopter Research Aircraft. In these studies both the remotely operated multiple array acoustic range (ROMAAR) and 2560-m linear microphone array laid out along a runway at the NASA Wallops Flight Center were utilized for the purpose of documenting the noise characteristics of the test helicopter during flyby and landing operations. By utilizing both the ROMAAR concept and the linear array, the data necessary to plot ground noise footprints and noise radiation patterns were obtained.

The results of these tests indicate that both the ground noise contours and the radiation patterns for this particular helicopter are symmetrical about the flight axis of the helicopter. It was also shown that increasing altitude did not significantly modify the radiation pattern while increasing speed caused higher levels and a distinct change in the radiation pattern.

REFERENCES

1. Stepniewski, W. Z.; and Schmitz, F. H.: Possibilities and Problems of Achieving Community Noise Acceptance of VTOL. Presented at Eight Congress of International Council of Aeronautical Sciences, ICAS Paper No. 72-34, Amsterdam, The Netherlands, Aug. 1972.
2. Maglieri, Domenic J.; Henderson, Herbert R.; and Hilton, David A.: Observed Variability of Aircraft Noise Footprint Measurements. NOISE-CON 77, Proceedings, George C. Maling, Jr., ed., Noise Control Found. c.1977, pp. 443-458.
3. Hilton, David A. and Henderson, Herbert R.: A Remotely Operated Multiple Array Acoustic Range (ROMAAR) and Its Application for the Measurement of Airplane Flyover Noise Footprints. NASA TM X-73986, 1976.



Figure 1.- Schematic illustration of geographical relationship between Wallops and Langley.

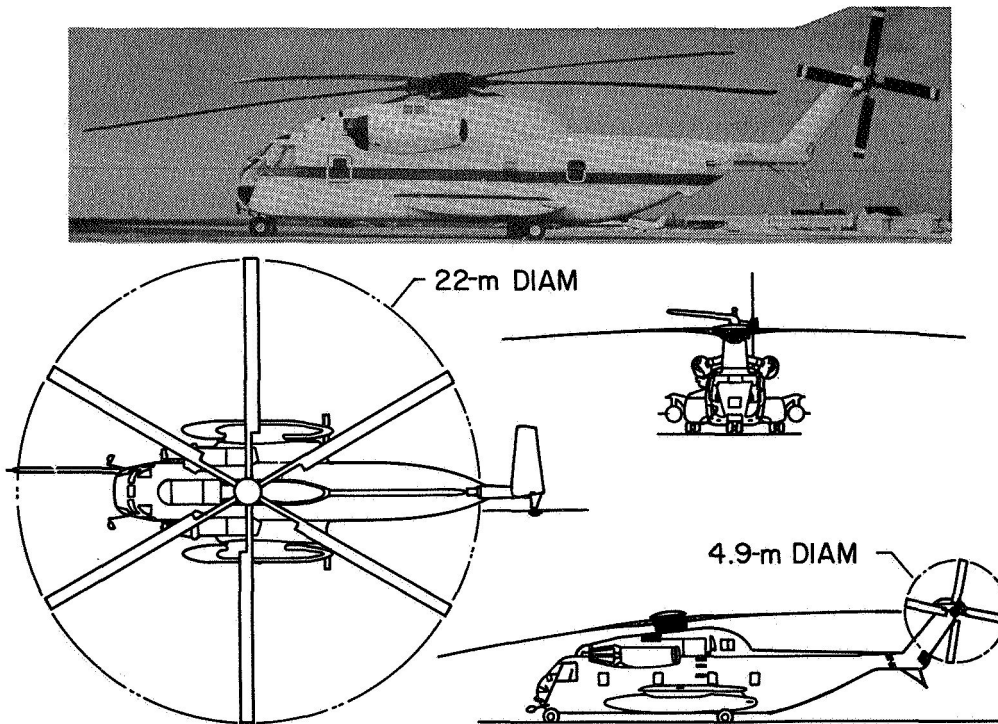
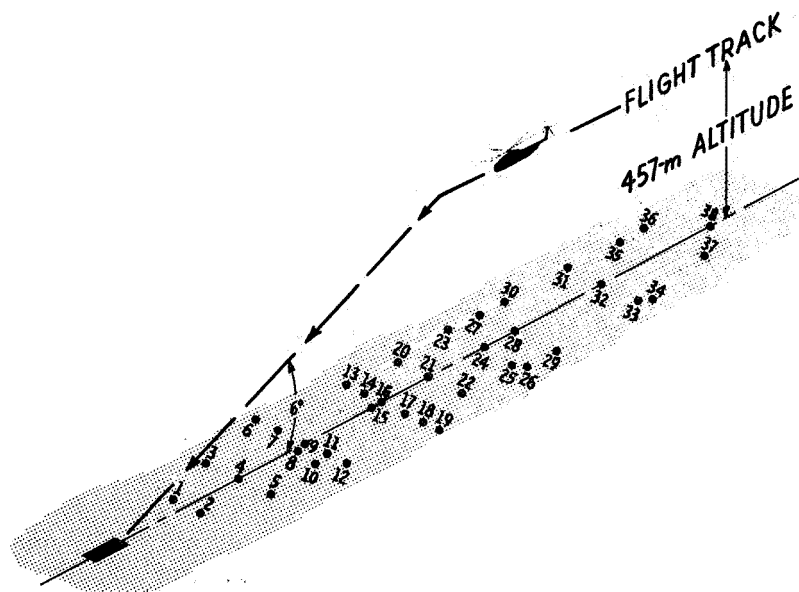
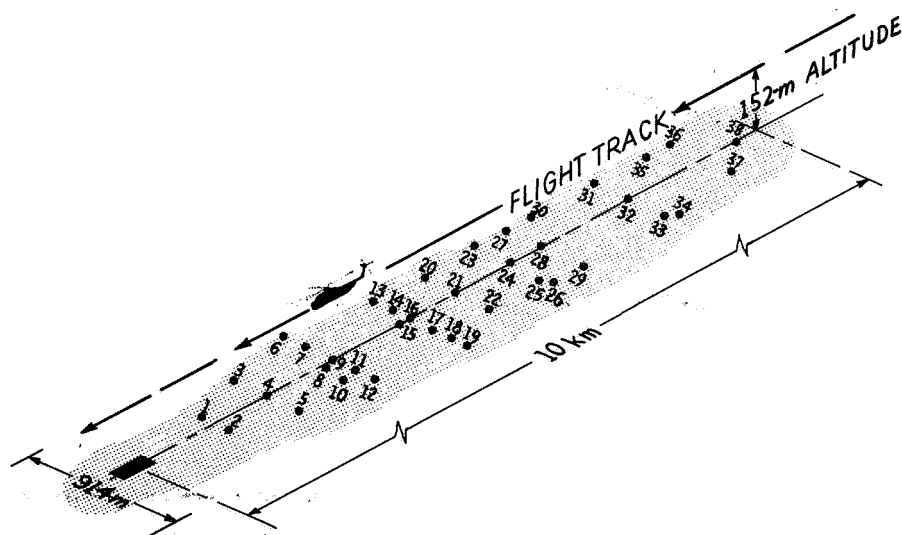


Figure 2.- Turbine-powered helicopter used in tests.

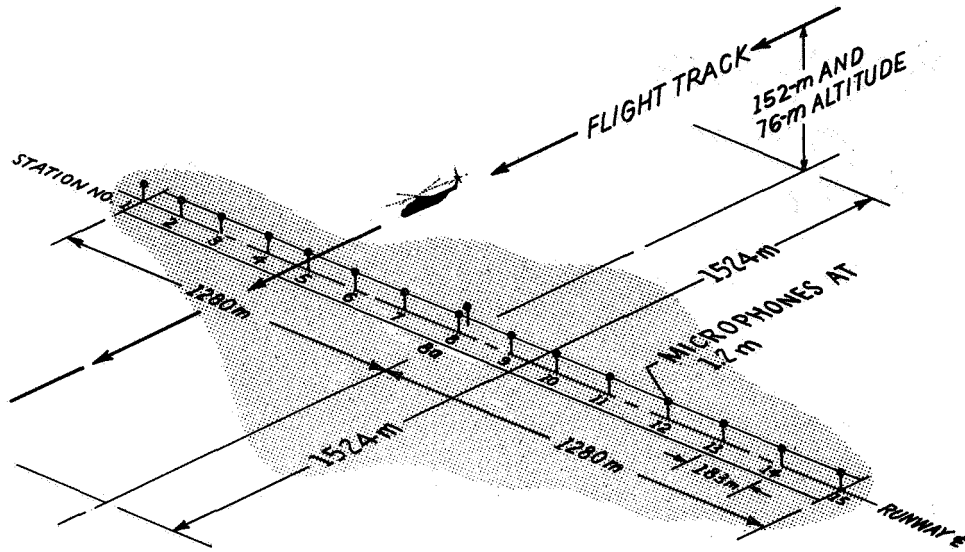


(a) Six-degree landing approach over ROMAAR.



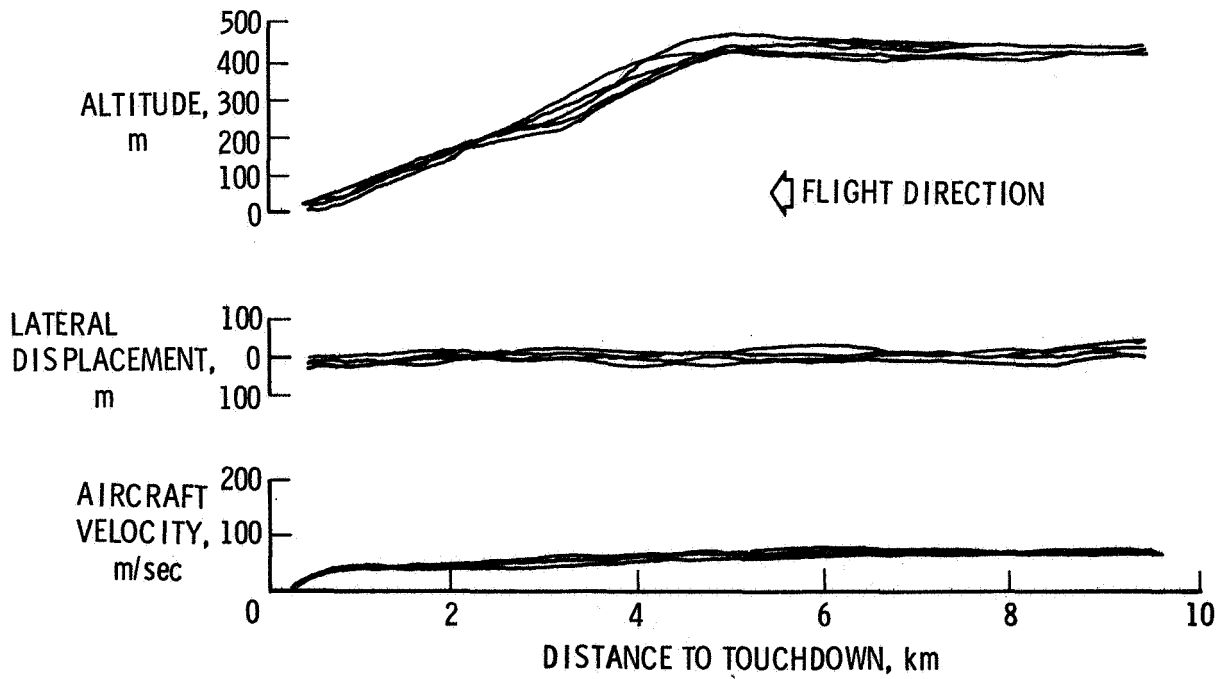
(b) Level flyby over ROMAAR.

Figure 3.- Schematic drawings of landing and level flyby operations performed by test helicopter.



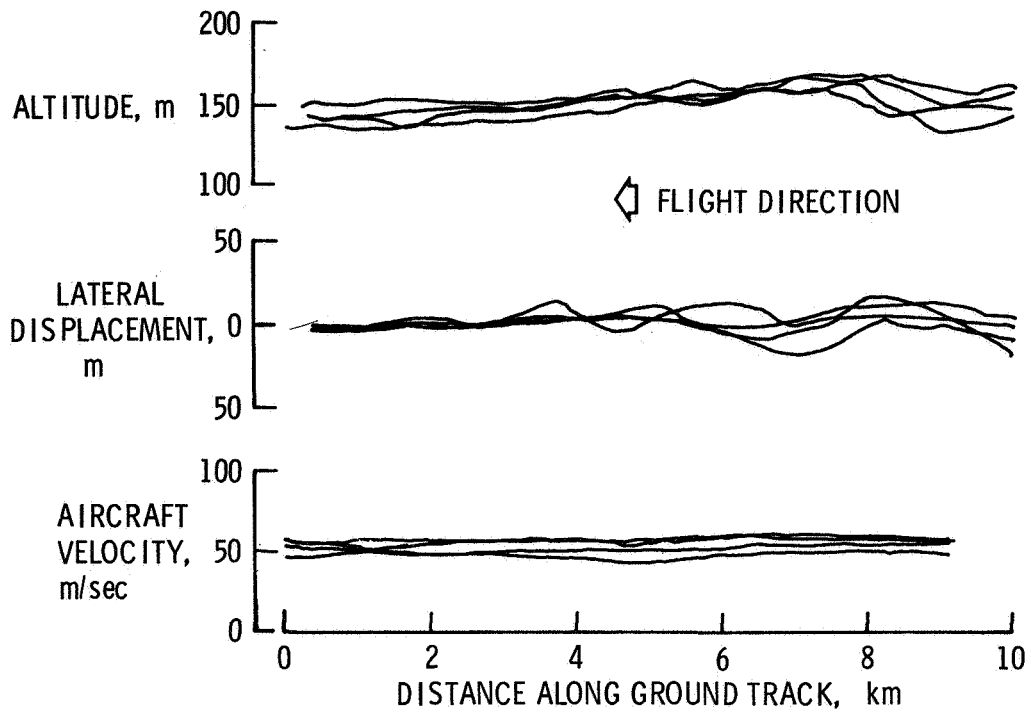
(c) Level flyby over linear array.

Figure 3.- Concluded.

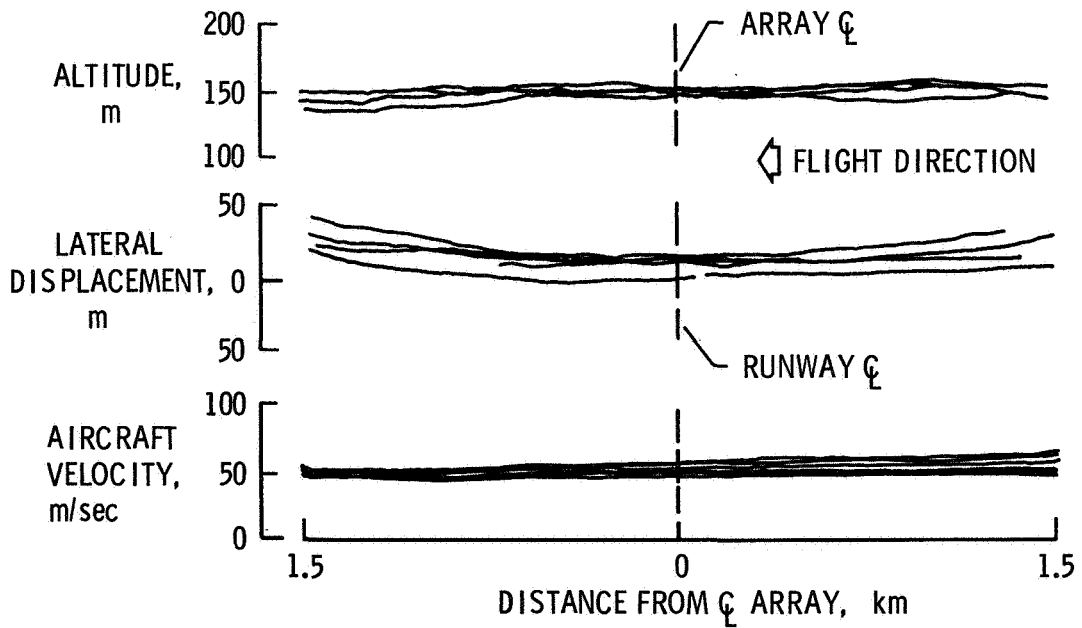


(a) Six-degree landing approach over ROMAAR.

Figure 4.- Radar tracking and aircraft velocity information.

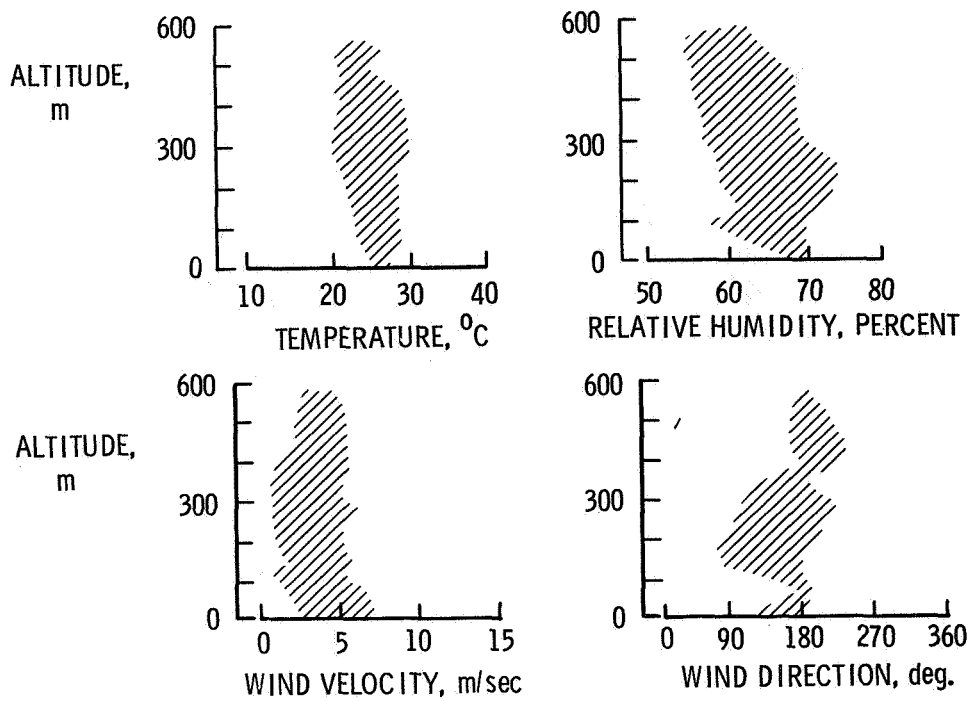


(b) Level flyby over ROMAAR.

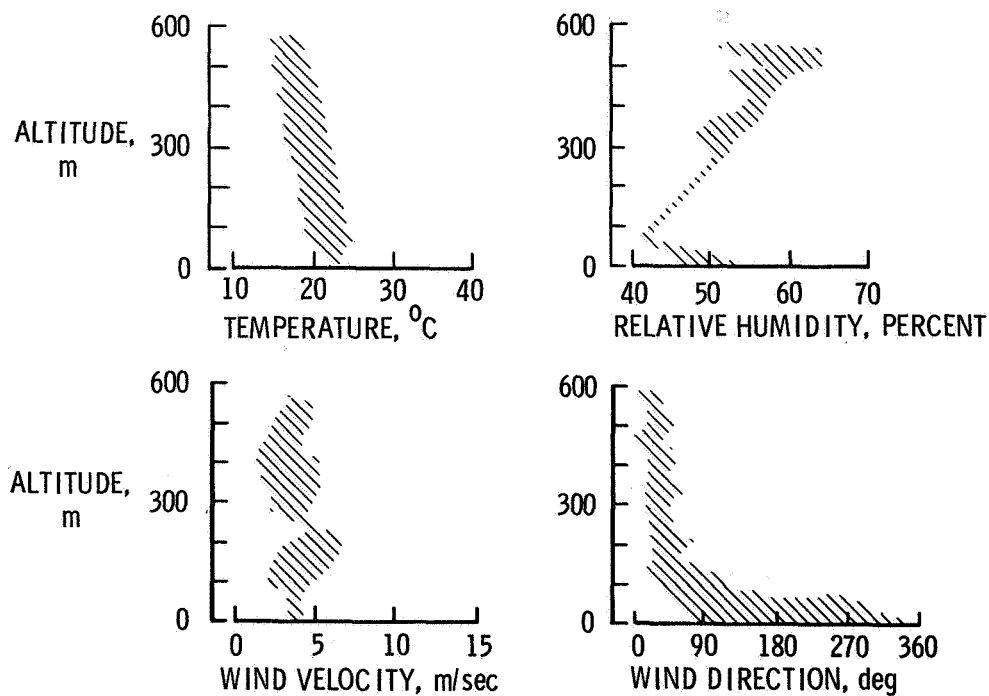


(c) Level flyby over linear array.

Figure 4.- Concluded.



(a) ROMAAR operations.



(b) Linear array operations.

Figure 5.- Variations in meteorological conditions for two test periods.

ROTOR rpm = 100 PERCENT TORQUE = 40 PERCENT

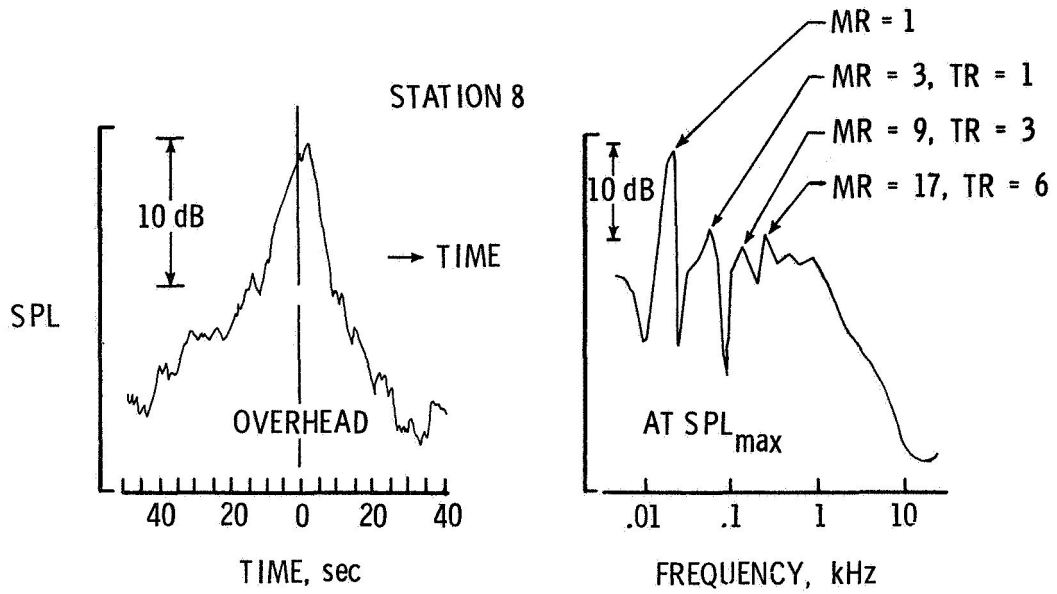


Figure 6.- Typical noise characteristics of test helicopter during level flyby. Altitude = 152 m, airspeed = 49 m/sec.

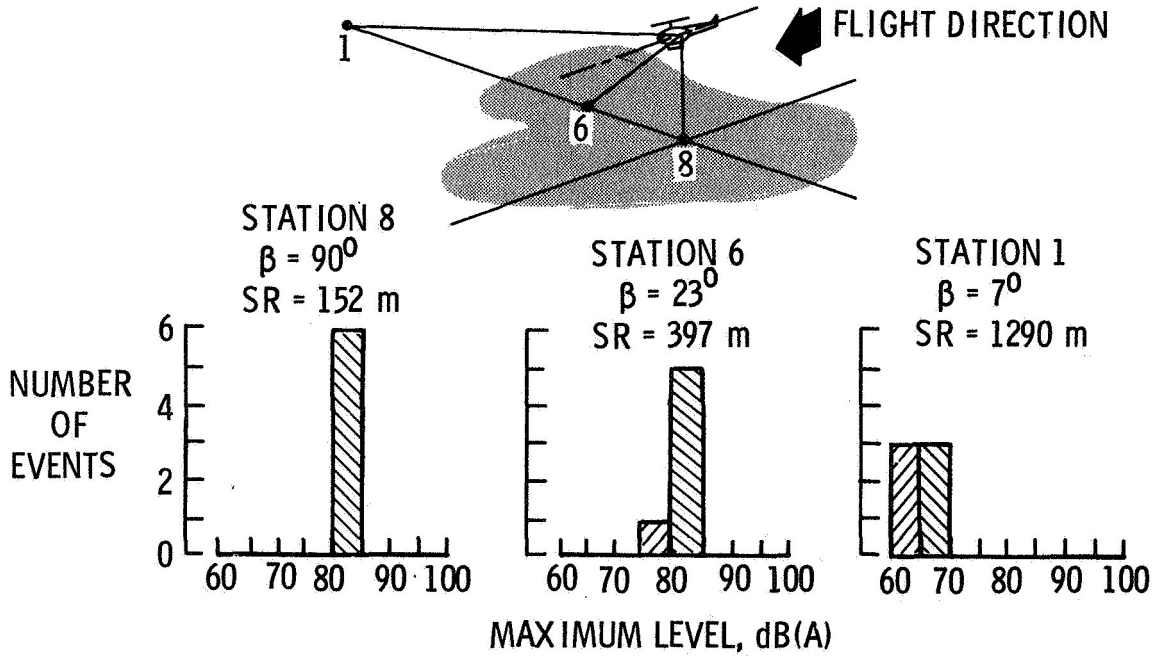


Figure 7.- Variation in maximum dB(A) levels over linear microphone array for six flights at 152-m altitude at speed of 49 m/sec.

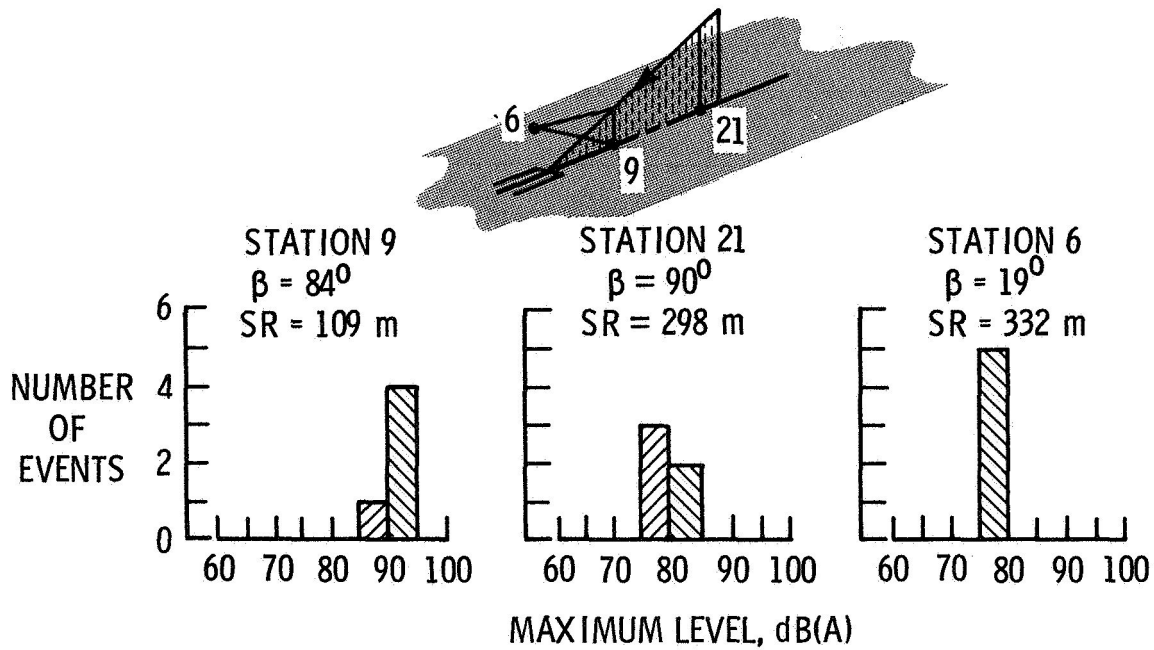


Figure 8.- Variation in maximum dB(A) levels for five six-degree landing approach flights over ROMAAR.

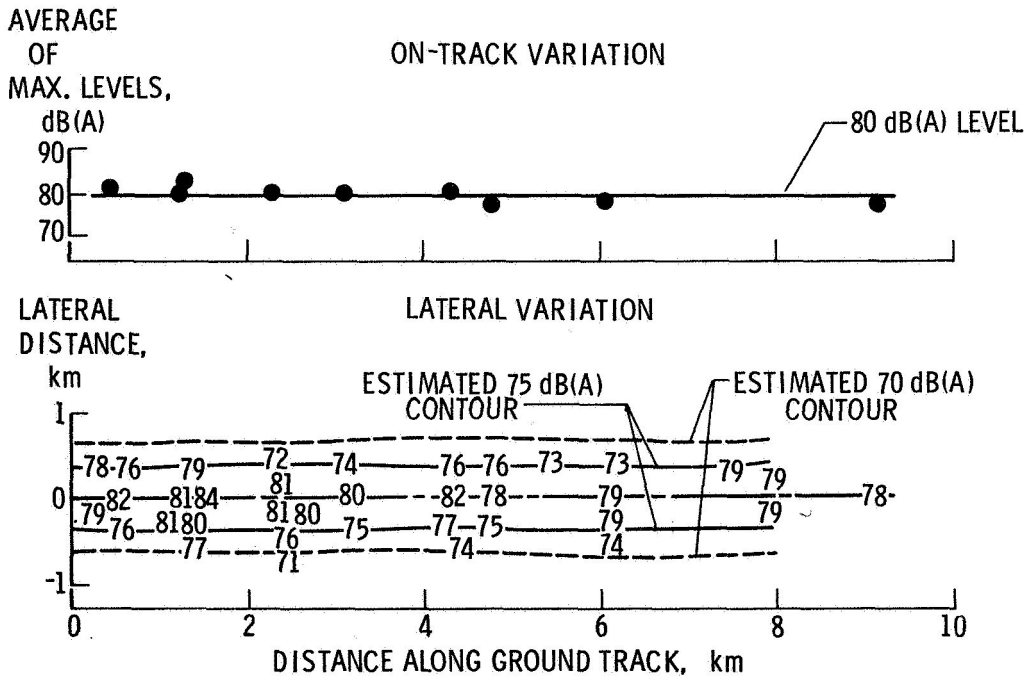


Figure 9.- Noise variability along ground track using ROMAAR for four level flybys at 152-m altitude and 49-m/sec airspeed.

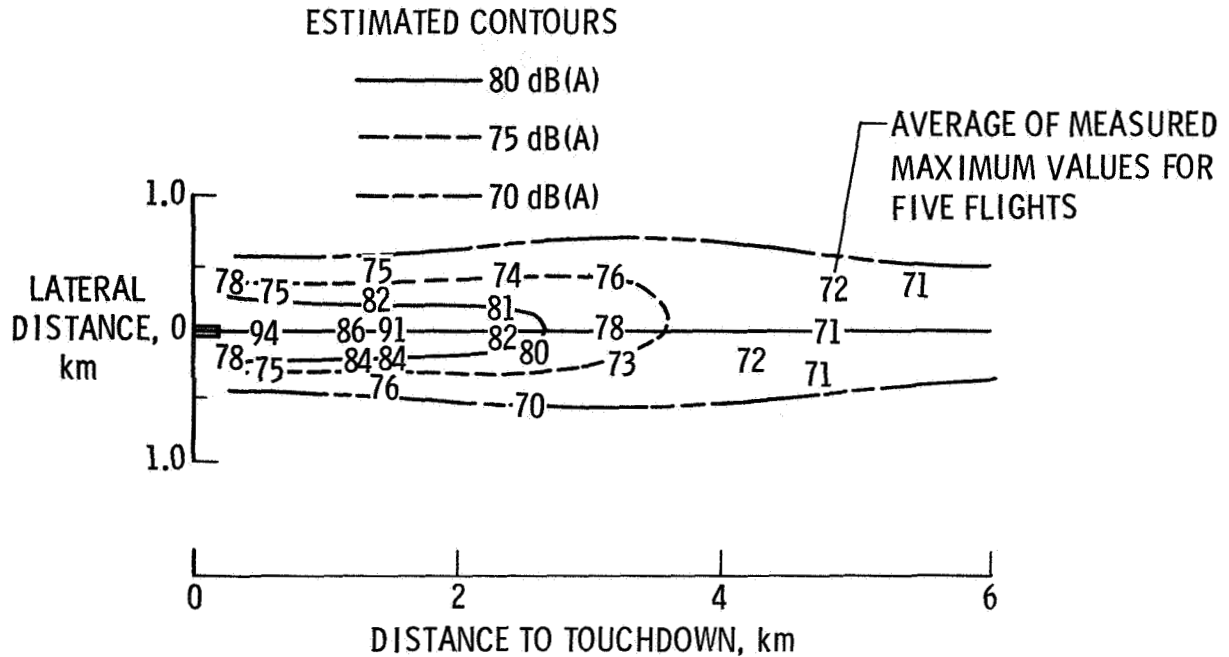


Figure 10.- Ground noise contours from five flights utilizing six-degree approach over ROMAAR.

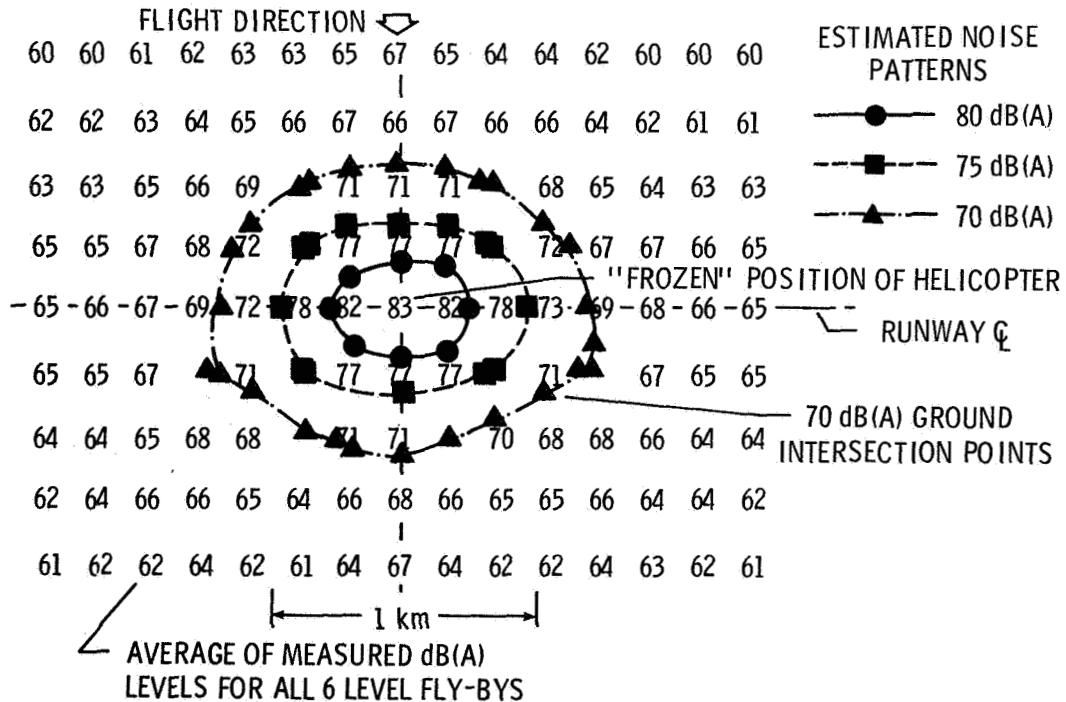


Figure 11.- Ground noise directivity patterns for six level flybys over linear array at 152-m altitude and 49-m/sec airspeed.

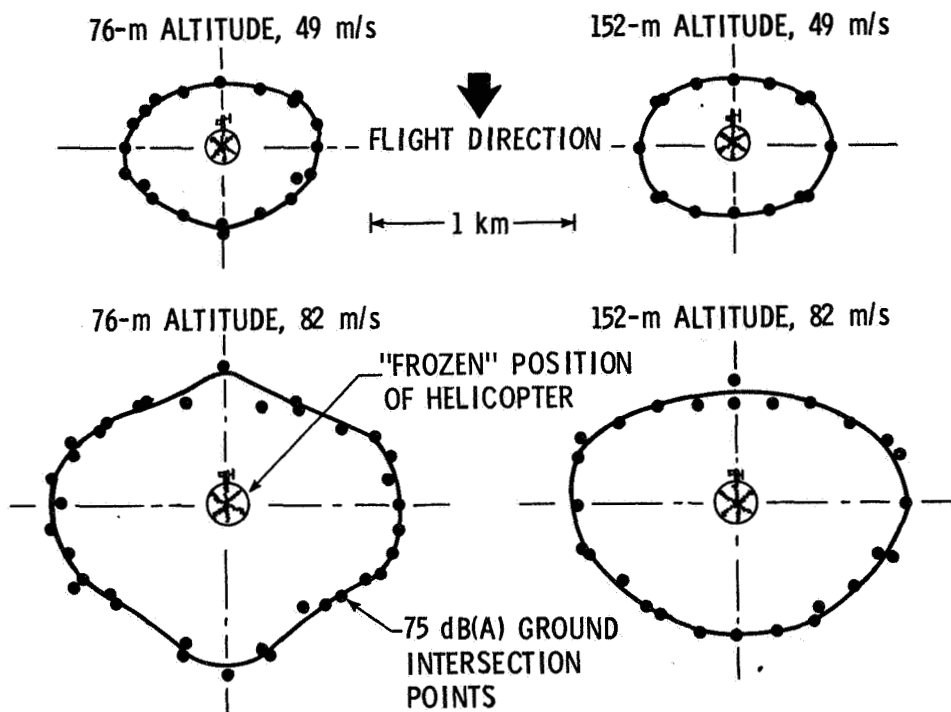


Figure 12.- Variations in 75-dB(A) noise directivity patterns over linear array for altitudes of 76 and 152 m and airspeeds of 49 and 82 m/sec.