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PERFORMANCE CHARACTERISTICS OF THE APOLLO ASTRONAUT BACKPACK ANTENNA

by Jefferson F. Lindsey III

Manned Spacecraft Center
Houston, Texas

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ABSTRACT

This report is a description of the flexible-steel-tape monopole used by the Apollo astronaut for extravehicular-activity communications. Antenna patterns and voltage-standing-wave-ratio measurements have been made at the NASA Manned Spacecraft Center, including both surface-reflection effects and free-space data. The antenna pattern data were taken at frequencies of 259.7, 279.0, and 296.8 megahertz, with surface-reflection effects included. The voltage standing-wave ratios in this range were under 2.0: 1, and the gains with surface-reflection effects and the astronaut standing ranged from the worst-case null of -5 decibels at 259.7 megahertz to +2 decibels at 279.0 megahertz, referenced to a perfect isotropic level of vertical-linear polarization. In the bending-over and lying-down positions, the gains range from -28 to +1 decibels, referenced to an isotropic level established in the standing position by substitution of a standard-gain dipole for the astronaut antenna. As a result, no height-gain correction factor in the transmission loss is required in the circuit margin calculations for the bending-over and lying-down positions.

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SUMMARY

The performance of the flexible-steel-tape monopole used by the Apollo astronaut for extravehicular-activity communications is described, based on measured data taken at the NASA Manned Spacecraft Center. Both surface-reflection effects and free-space data are included. The voltage standing-wave ratio is found to range from 1.08: 1 at 279.0 megahertz to 1.8: 1 at 296.8 megahertz. The gains on the horizon with surface-reflection effects range from a worst-case null of -5 decibels at 259.7 and 296.8 megahertz to a peak level of +2 decibels at 279.0 megahertz, referenced to a perfect isotropic level of vertical-linear polarization. In the bending-over and lying-down positions, the gains range from -28 to +1 decibels, referenced to the isotropic level established in the standing position by substitution of a standard-gain dipole for the astronaut antenna. As a result, no height-gain correction factor in the transmission loss is required in the circuit margin calculations for the bending-over or lying-down positions.

INTRODUCTION

This report is a description of the performance and operation of the flexible-steel-tape monopole used by the Apollo astronaut for extravehicular-activity (EVA) communications. Antenna patterns and voltage-standing-wave-ratio (VSWR) measurements have been taken in the very-high-frequency (vhf) range with the antenna mounted on the backpack. Patterns with smooth-surface reflection effects and free-space data are included.

The blade monopole antenna is constructed of flexible steel tape approximately 10.25 inches long. The steel tape is potted in a 1.25-inch-diameter cup with a potting compound having a dielectric constant of 1.8 and a loss factor of less than 0.015. The total weight of the antenna, including the cable and connector, is 3.5 ounces. The antenna was developed and tested for use on the Apollo astronaut backpack in June 1966 by J. F. Lindsey and G. H. Nason of the NASA Manned Spacecraft Center (MSC) and is now produced by a subcontractor. The test conditions, measured results, and conclusions are discussed.

TEST CONDITIONS

The test setup for the VSWR measurements is shown in figure 1. Standard mismatches of 1.25:1 and 1.75:1 were used to insure the proper calibration of the setup. The measurements were taken in a clear area behind building 14 at MSC, using an electrical mockup of the backpack. The VSWR was measured at 5-megahertz intervals in the 250- to 310-megahertz range. The VSWR data may be used either for free-space operations or on the lunar surface.

The antenna was mounted on the oxygen purge system (OPS), which is mounted on the portable life-support system (PLSS), as shown in figure 2. This combination, generally referred to as the backpack, was mounted on a live subject during the VSWR measurements.

The antenna pattern measurements were taken on the MSC ground-reflection range. The test setup with reflection effects included is shown in figure 3. The three operational frequencies of 259.7, 279.0, and 296.8 megahertz were used. A range length of 1000 feet was chosen to insure adequate simulation of long-range multipath smooth-surface reflection effects. With a transmitting antenna 24 feet above the ground, which corresponds to the lunar-module EVA antenna and the 6-foot height of the astronaut's backpack, the grazing angle is found to be 1.7°. At this small grazing angle, the Fresnel reflection coefficient is close to -1 for a wide range of dielectric constants (ref. 1). For example, with a dielectric constant $\epsilon_r = 4.0$, the vertical reflection coefficient is 0.93, and with $\epsilon_r = 1.4$, the vertical reflection coefficient is 0.88. The dielectric constants for the MSC antenna range and the lunar surface are believed to be within this range (refs. 2 and 3). Also, at the 1000-foot range, the path difference between the direct and reflected wave is found to be 4 inches, which is much less than a one-half wavelength; therefore, destructive multipath smooth-surface reflection effects corresponding to longer communication ranges do exist.

The transmitting antenna was a vertically polarized dipole, the pattern of which closely approximates the pattern of the lunar-module astronaut EVA antenna. The backpack antenna was used for receiving, and the gain of the antenna was obtained by substitution of a standard-gain reference dipole at the 6-foot standing height. The isotropic level was taken as 2 decibels below the dipole level. Measurements were taken in the vhf range at 259.7, 279.0, and 296.8 megahertz, with the astronaut in the standing, bending-over, and lying-down (face down) positions. The isotropic level established with the reference dipole at the 6-foot standing height was used for the bending-over and lying-down positions; thus, circuit margin calculations do not need to include a height-gain correction factor for the lower antenna heights in the bending-over and lying-down positions.

For the free-space patterns, the Ellington Air Force Base antenna range was used with an electrical mockup of an astronaut. A standard-gain reference dipole with 2 decibels of gain was used to establish the isotropic level.

MEASURED RESULTS

The results for the VSWR tests are shown in figure 4. The voltage standing-wave ratios at the operating frequencies are 1.6:1 at 259.7 megahertz, 1.08:1 at 279.0 megahertz, and 1.71:1 at 296.8 megahertz. These ratios are within the normally specified value of 2.0:1 for transmitting antennas. The VSWR for operation of the antenna on a 48-inch-diameter ground plane is also shown in figure 4. The 48-inch-diameter ground plane is used for acceptance testing at the subcontractor facility. The resonant frequency on the 48-inch-diameter ground plane is 260 megahertz; whereas, on the smaller backpack ground plane, the resonant point is near 278 megahertz. Before the addition of the OPS, the antenna was mounted on the PLSS, and the VSWR characteristics were better than the measurements after the addition of the OPS. The VSWR with the PLSS mounting was 1.5:1 at 259.7 megahertz and 1.6:1 at 296.8 megahertz.

The antenna-pattern-measurement results are tabulated in table I. The coordinate system used for the patterns is shown in figure 5, with variation of Φ from 0° to 360°. The $\Phi = 0^\circ$ angle corresponds to the astronaut facing toward the lunar module or another astronaut. At $\Phi = 90^\circ$, the antenna gain is defined with the left shoulder toward the other station; at $\Phi = 180^\circ$, the antenna gain is defined with the astronaut facing away from the other station; and at $\Phi = 270^\circ$, the antenna gain is defined at the right shoulder. For the free-space patterns, the elevation angle θ varies from 0° above the astronaut to 90° on the horizon and to 180° below the astronaut.

The patterns with surface-reflection effects included are given in figure 6. These patterns may be used in determining the ranges on the lunar surface. In the standing position, the worst-case gain is 5 decibels below a perfect isotropic level of vertical linear polarization. The maximum gain occurs at the relay frequency of 279.0 megahertz and is found to be 2 decibels above the reference isotropic level. The gain measurements taken in the bending-over and lying-down positions are referenced to the isotropic level obtained with the reference dipole vertically polarized at the 6-foot standing height; thus, for communications range margin calculation, the transmission-loss curve for a 6-foot astronaut antenna may be used without any height-gain correction factors. In addition, no polarization loss factor is required. In the bending-over and lying-down positions, the maximum level is 1 decibel above the reference isotropic level, and the worst-case level is 28 decibels below the reference isotropic level. The average levels are those obtained for about one-half of the pattern.

The free-space patterns are shown in figure 7. These patterns may be used for antenna-performance extravehicular activities in space. The patterns are referenced to an isotropic level of vertical-linear polarization; thus, polarization loss factors are needed for circuit margin calculations. The relatively high level of +1 decibel obtained in the bending-over and lying-down positions can be explained by examining the free-space patterns. The maximum gain occurs around $\theta = 160^\circ$, near the astronaut's feet.

CONCLUDING REMARKS

Antenna pattern data have been taken with surface-reflection effects at the three operational frequencies of 259.7, 279.0, and 296.8 megahertz on the Apollo astronaut backpack antenna. The voltage standing-wave ratios in this frequency range were under 2.0: 1 at each frequency, and the gains with surface-reflection effects and the astronaut standing ranged between -5 and +2 decibels, referenced to a perfect isotropic level of vertical-linear polarization. In the bending-over and lying-down positions, the gains range from -28 to +1 decibels, referenced to an isotropic level established in the standing position by substitution of a standard-gain dipole for the astronaut antenna. As a result, no height-gain correction factor in the transmission loss is required in the circuit margin calculation for the bending-over and lying-down positions. The free-space gains ranged from -30 to +1 decibels, referenced to a perfect isotropic of vertical polarization.

Manned Spacecraft Center
National Aeronautics and Space Administration
Houston, Texas, December 16, 1968
914-50-50-09-72

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Pettengill, G. H.; and Henry, J. C.: Radar Measurements of the Lunar Surface. Advances in the Astronautical Sciences, vol. 8. Plenum Press, 1963, pp. 564-570.

TABLE I. - ABSOLUTE GAINS OF APOLLO ASTRONAUT BACKPACK ANTENNA

Frequency, MHz	Absolute gain referenced to vertical isotropic level, dB											
	Reflection effects included									Free space		
	Standing			Bending over (a)			Lying face down (a)					
	Max.	Av	Min.	Max.	Av	Min.	Max.	Av	Min.	Max.	Av	Min.
259.7	0	-2	-5	-1	-13	-28	-8	-15	-22	-0.5	-5	-26
279.0	+2	0	-3	+1	-10	-25	-6	-14	-22	+1	-4	-30
296.8	0	-2	-5	-2	-12	-25	-8	-15	-28	0	-5	-28

[a]The gains were obtained by using the standard-gain dipole at the 6-foot standing level and by using 2 decibels for the gain of the dipole over the isotropic level.

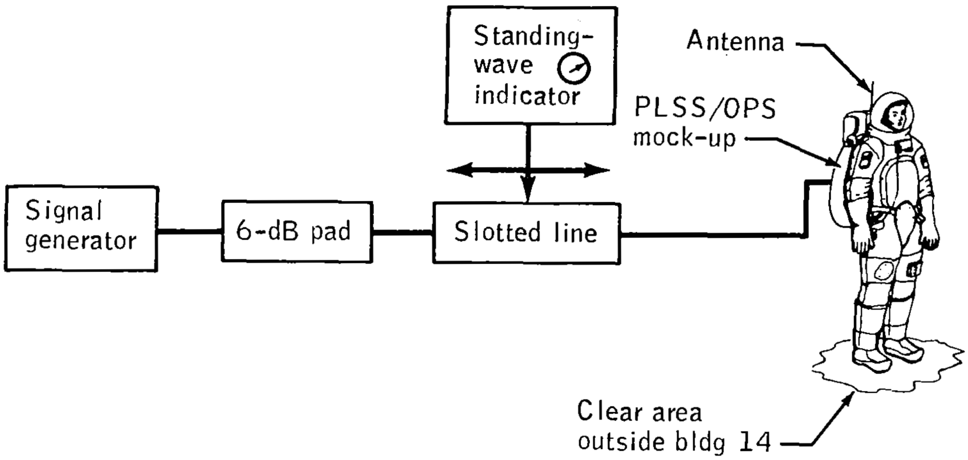


Figure 1. - The VSWR test setup.

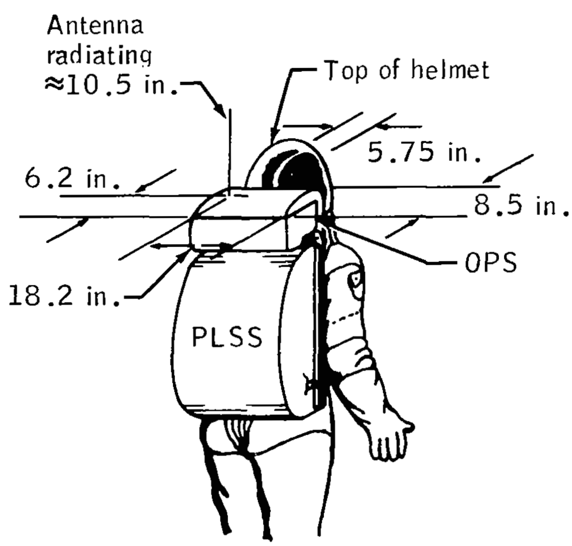


Figure 2. - Antenna mounting on the OPS.

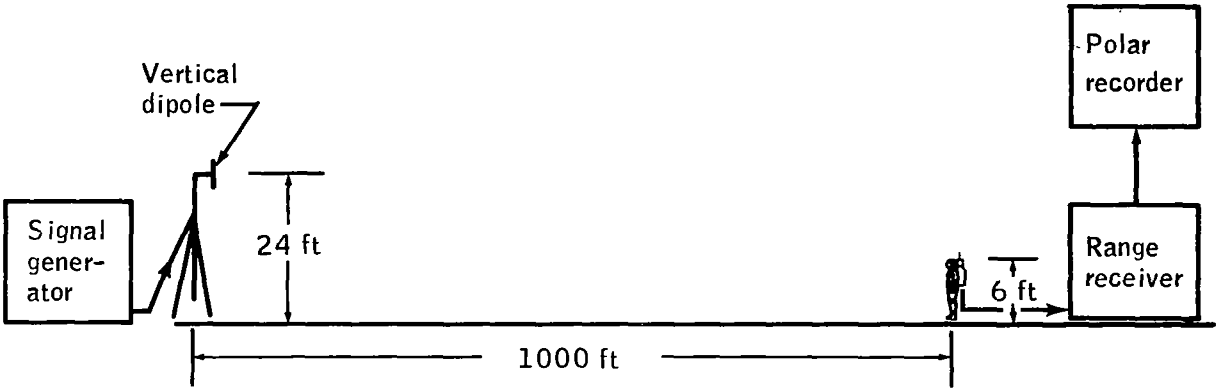


Figure 3. - Antenna pattern setup.

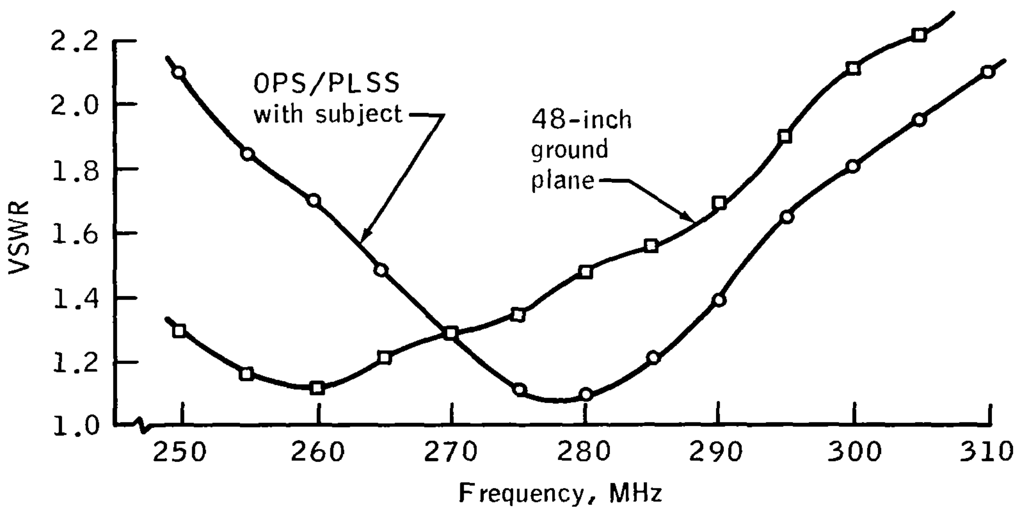


Figure 4. - The VSWR versus frequency.

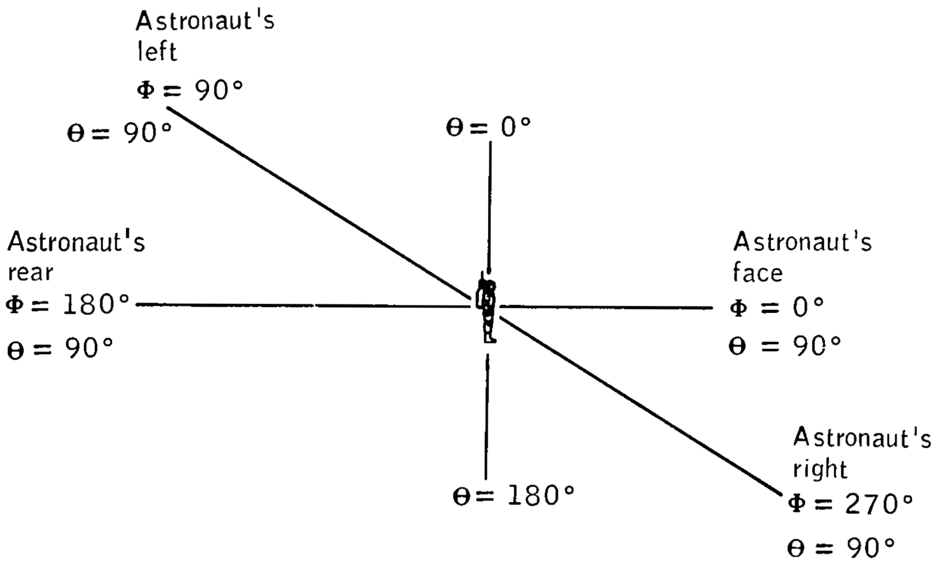
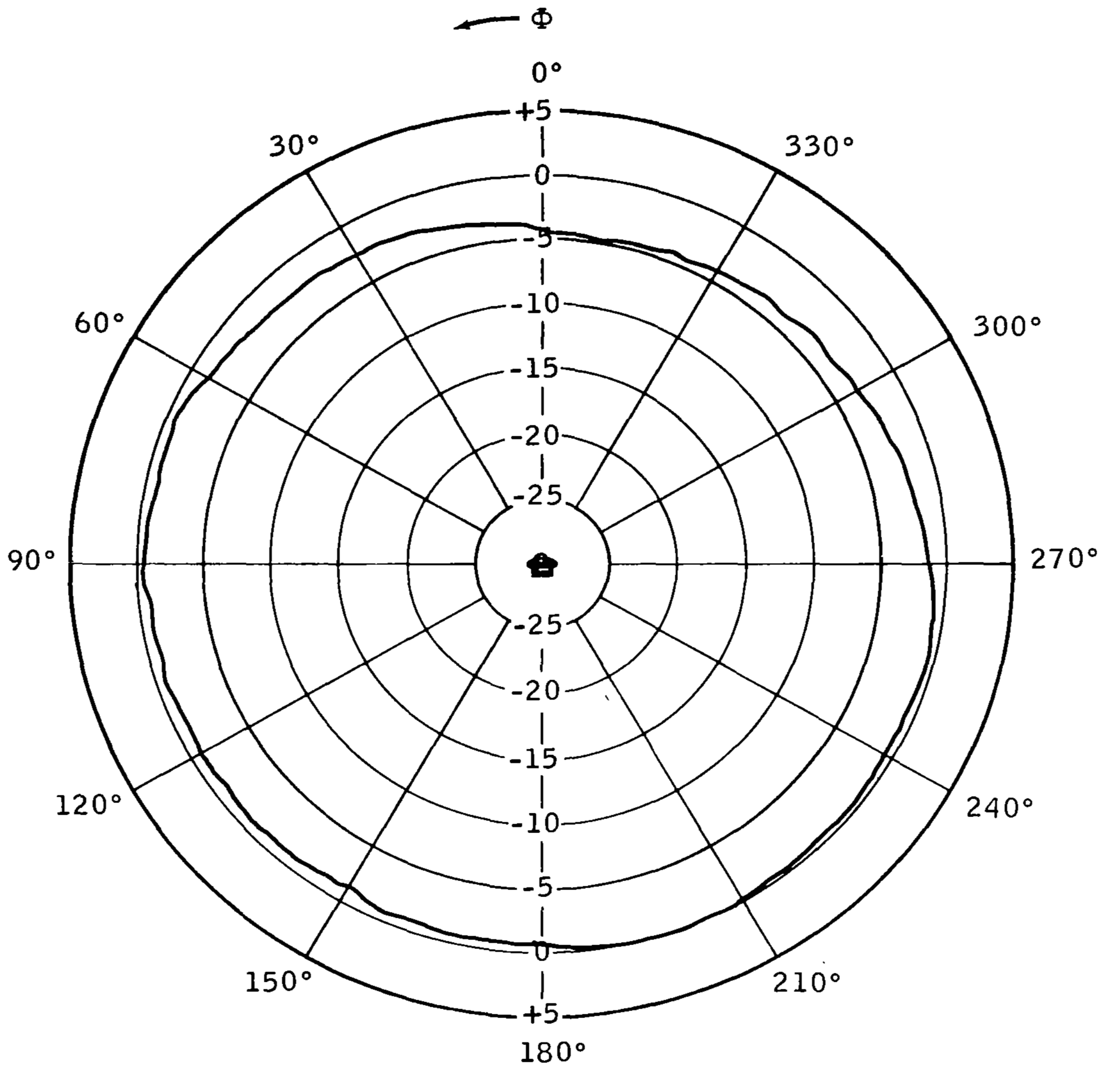


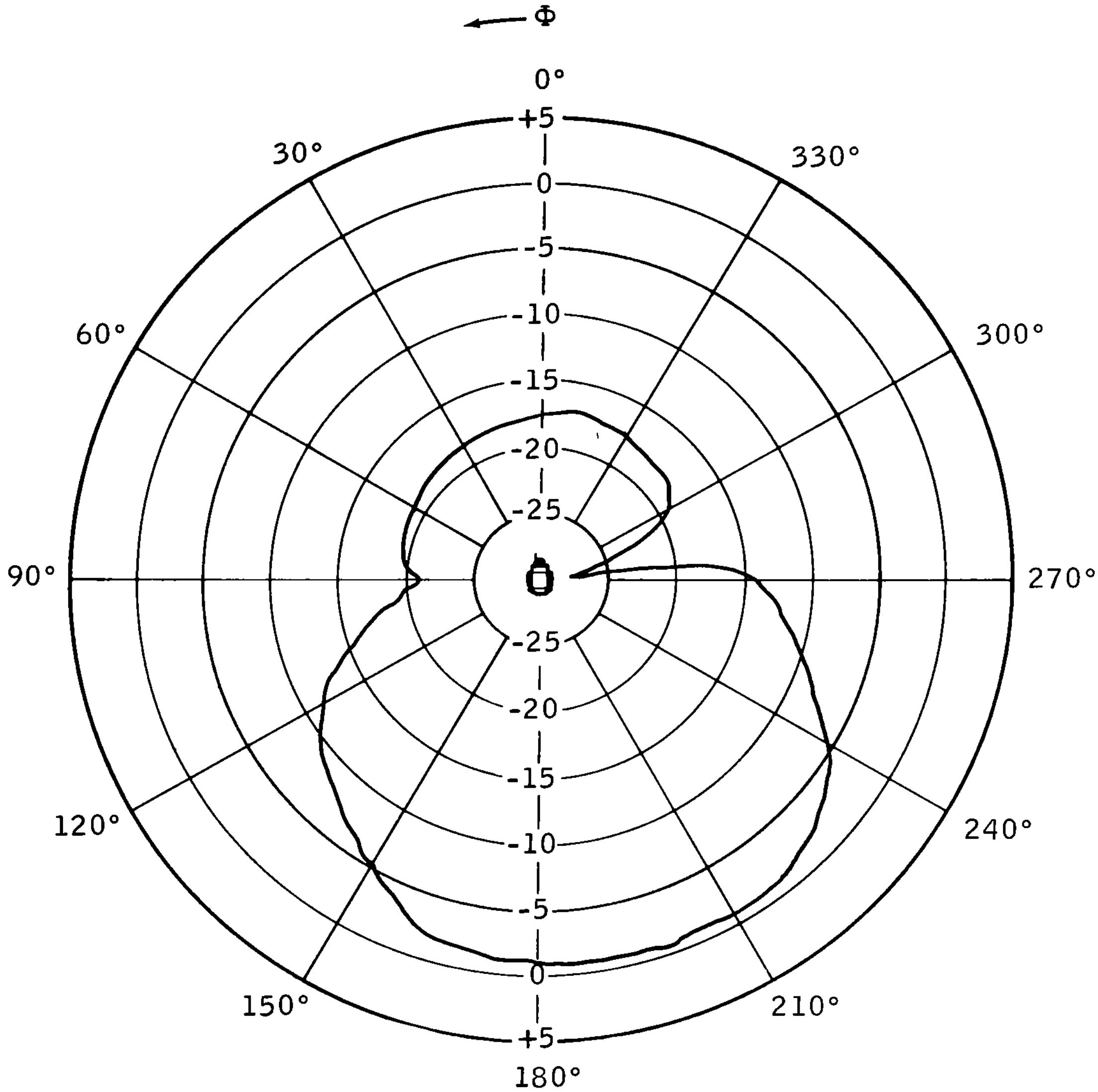
Figure 5. - Pattern coordinate system.



The gains are referenced to a perfect isotropic level of vertical-linear polarization established by substitution of a reference dipole for the backpack antenna.

(a) Standing position and f = 259.7 MHz.

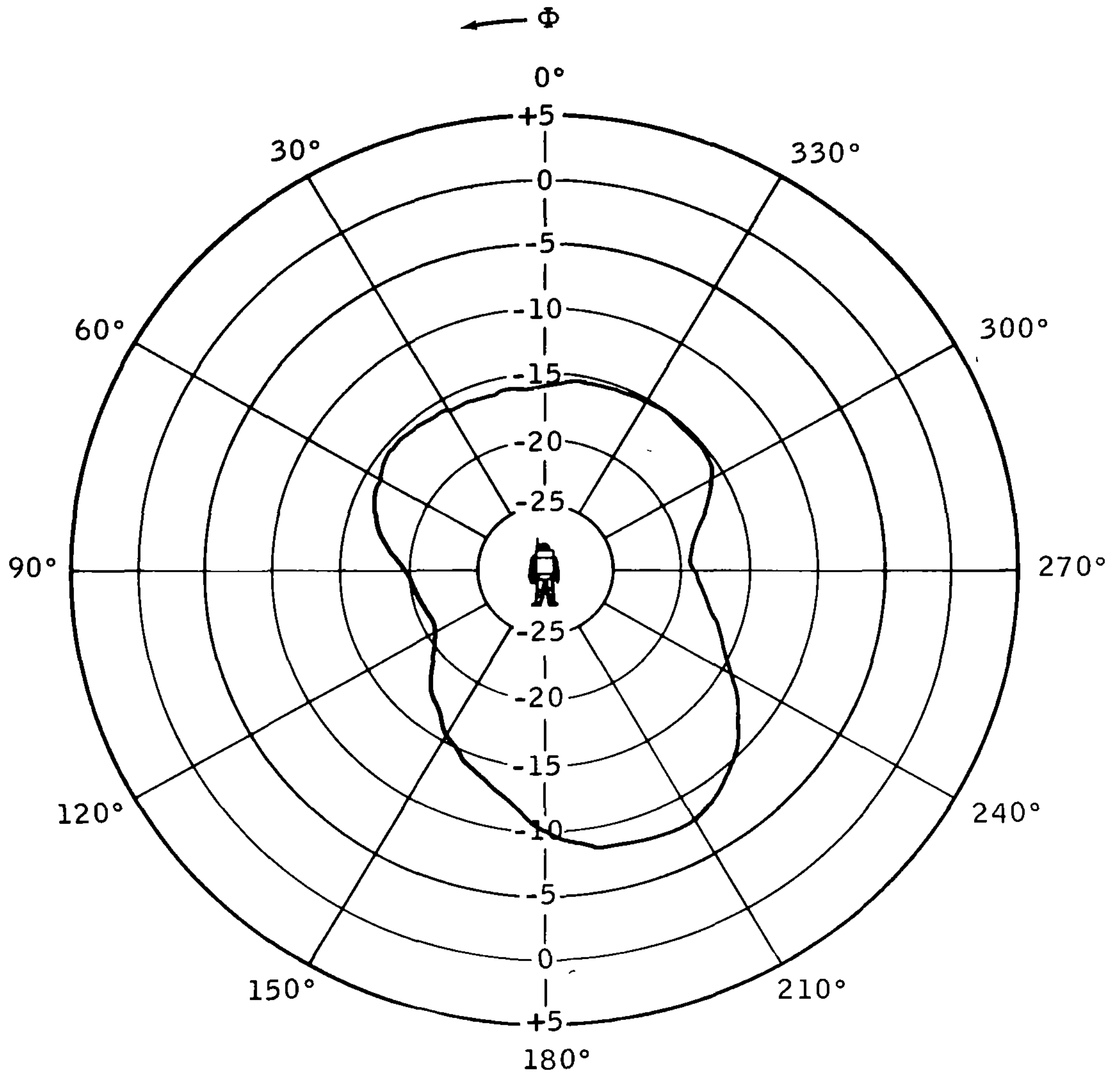
Figure 6. - Apollo astronaut monopole antenna pattern with surface reflection included.



The gains are referenced to a perfect isotropic level of vertical-linear polarization established at the 6-foot standing height by substitution of a reference dipole.

(b) Bending-over position and f = 259.7 MHz.

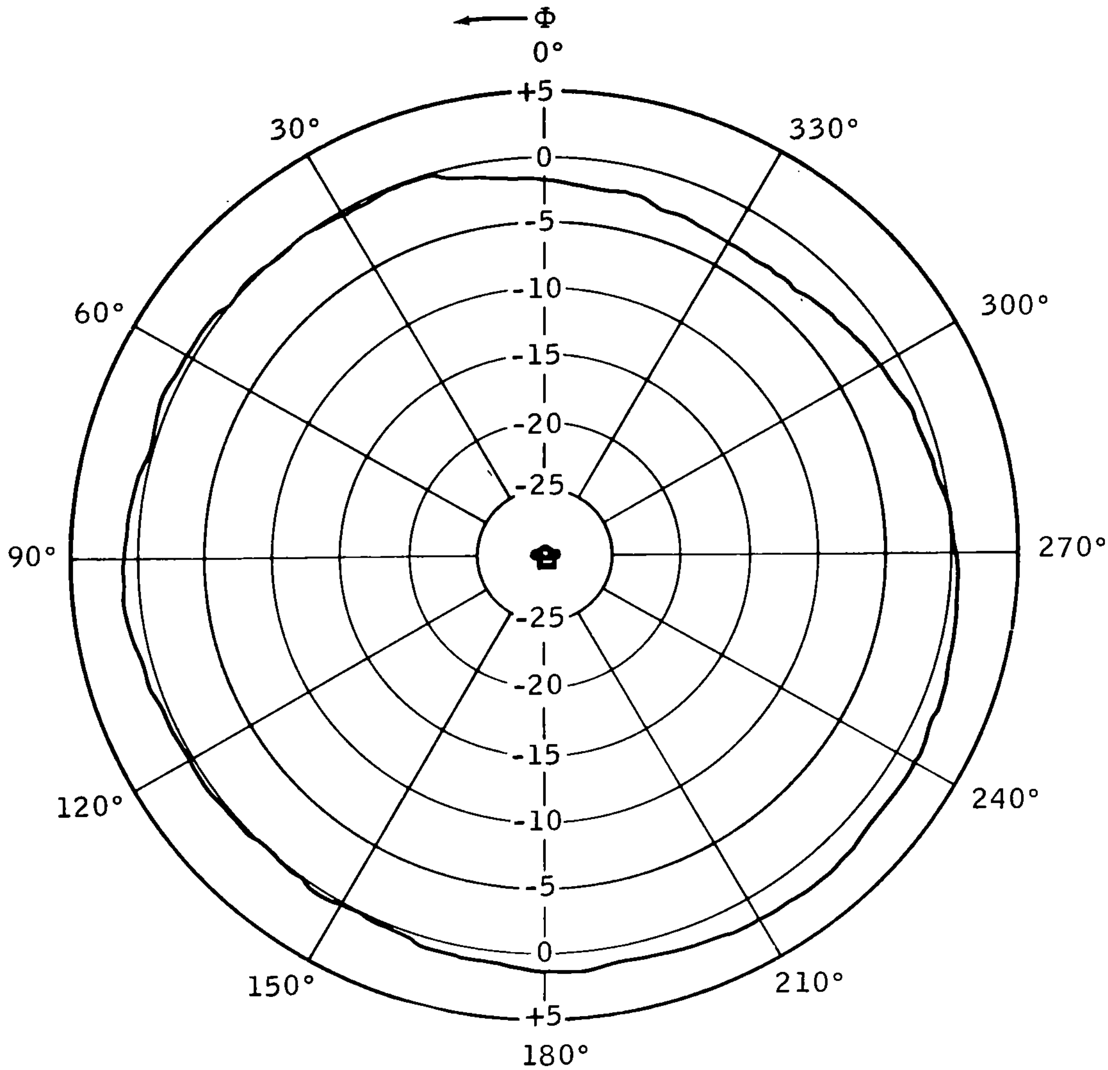
Figure 6. - Continued.



The gains are referenced to a perfect isotropic level of vertical-linear polarization established at the 6-foot standing height by substitution of a reference dipole.

(c) Lying-face-down position and f = 259.7 MHz.

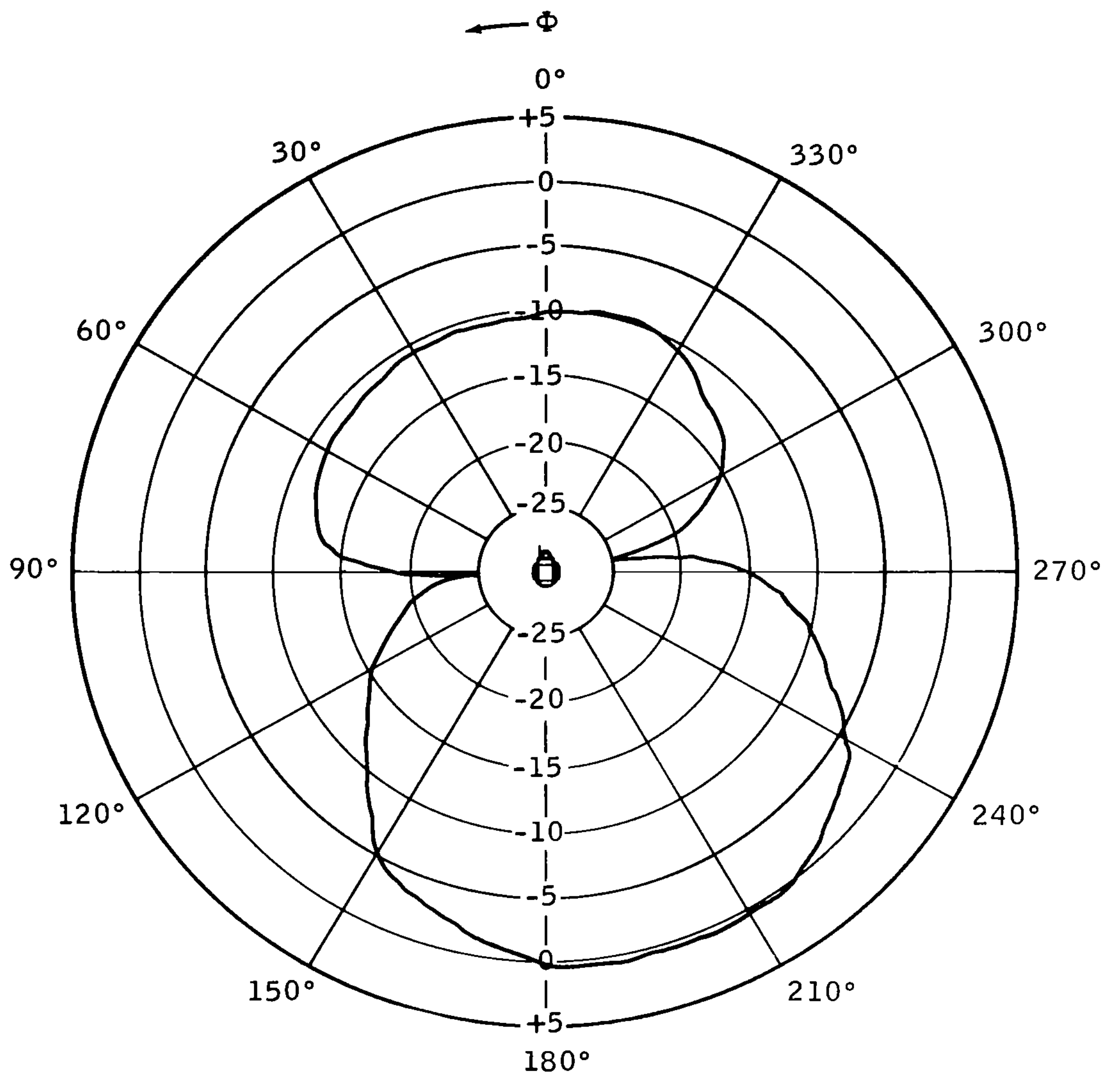
Figure 6. - Continued.



The gains are referenced to a perfect isotropic level of vertical-linear polarization established by substitution of a reference dipole for the backpack antenna.

(d) Standing position and f = 279. 0 MHz.

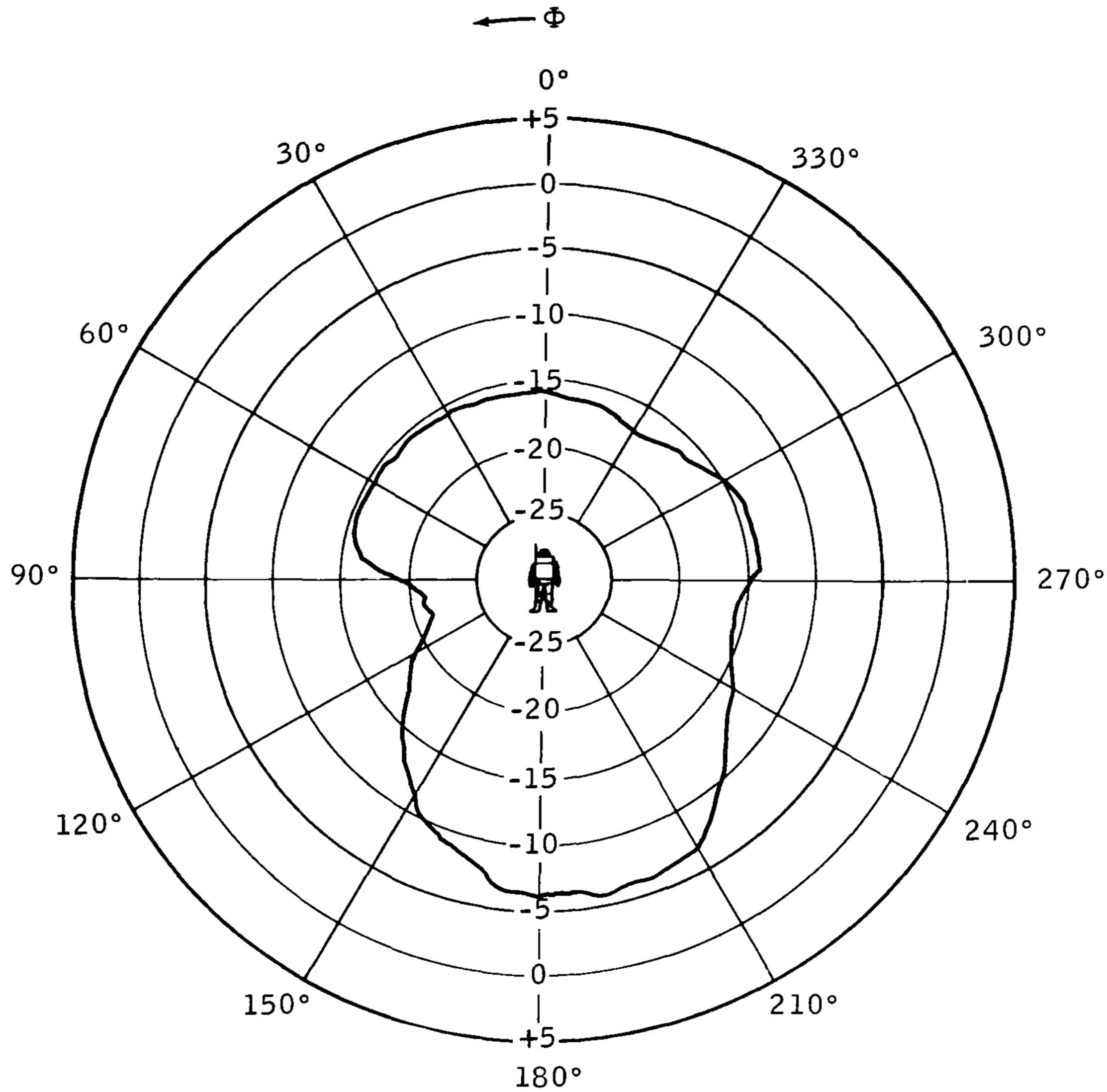
Figure 6. - Continued.



The gains are referenced to a perfect isotropic level of vertical-linear polarization established at the 6-foot standing height by substitution of a reference dipole.

(e) Bending-over position and f = 279.0 MHz.

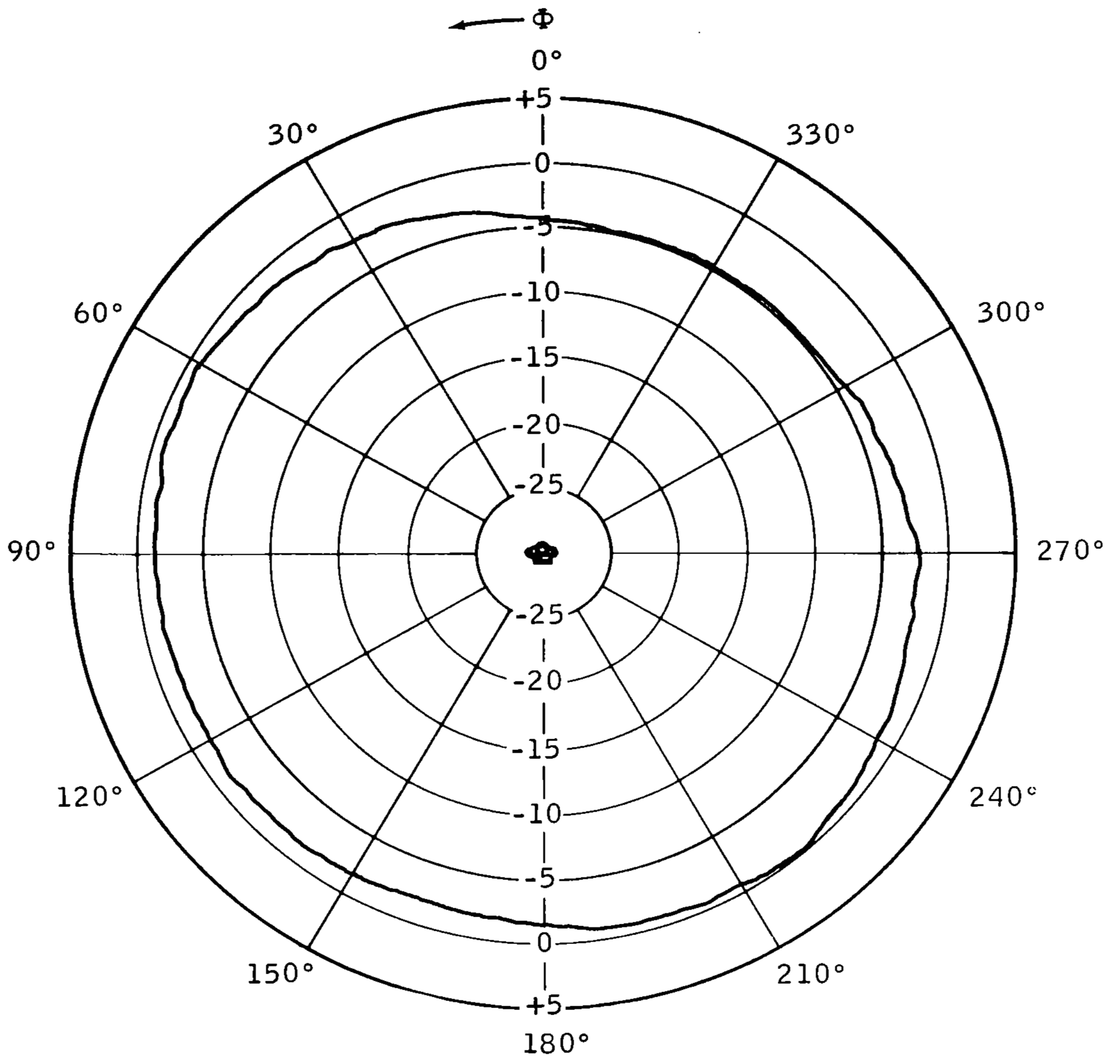
Figure 6. - Continued.



The gains are referenced to a perfect isotropic level of vertical-linear polarization established at the 6-foot standing height by substitution of a reference dipole.

(f) Lying-face-down position and f = 279.0 MHz.

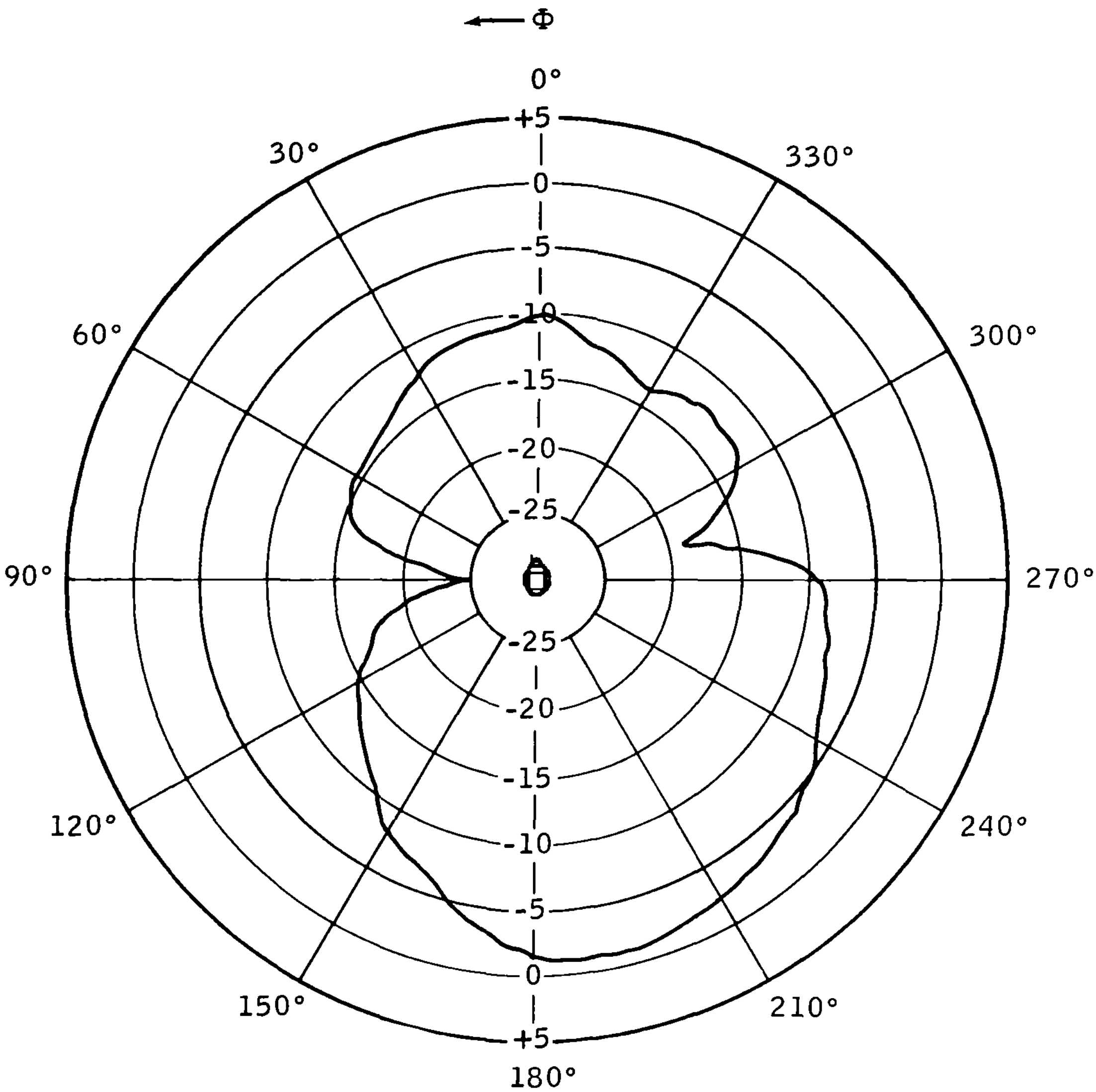
Figure 6. - Continued.



The gains are referenced to a perfect isotropic level of vertical-linear polarization established by substitution of a reference dipole for the backpack antenna.

(g) Standing position and f = 296.8 MHz.

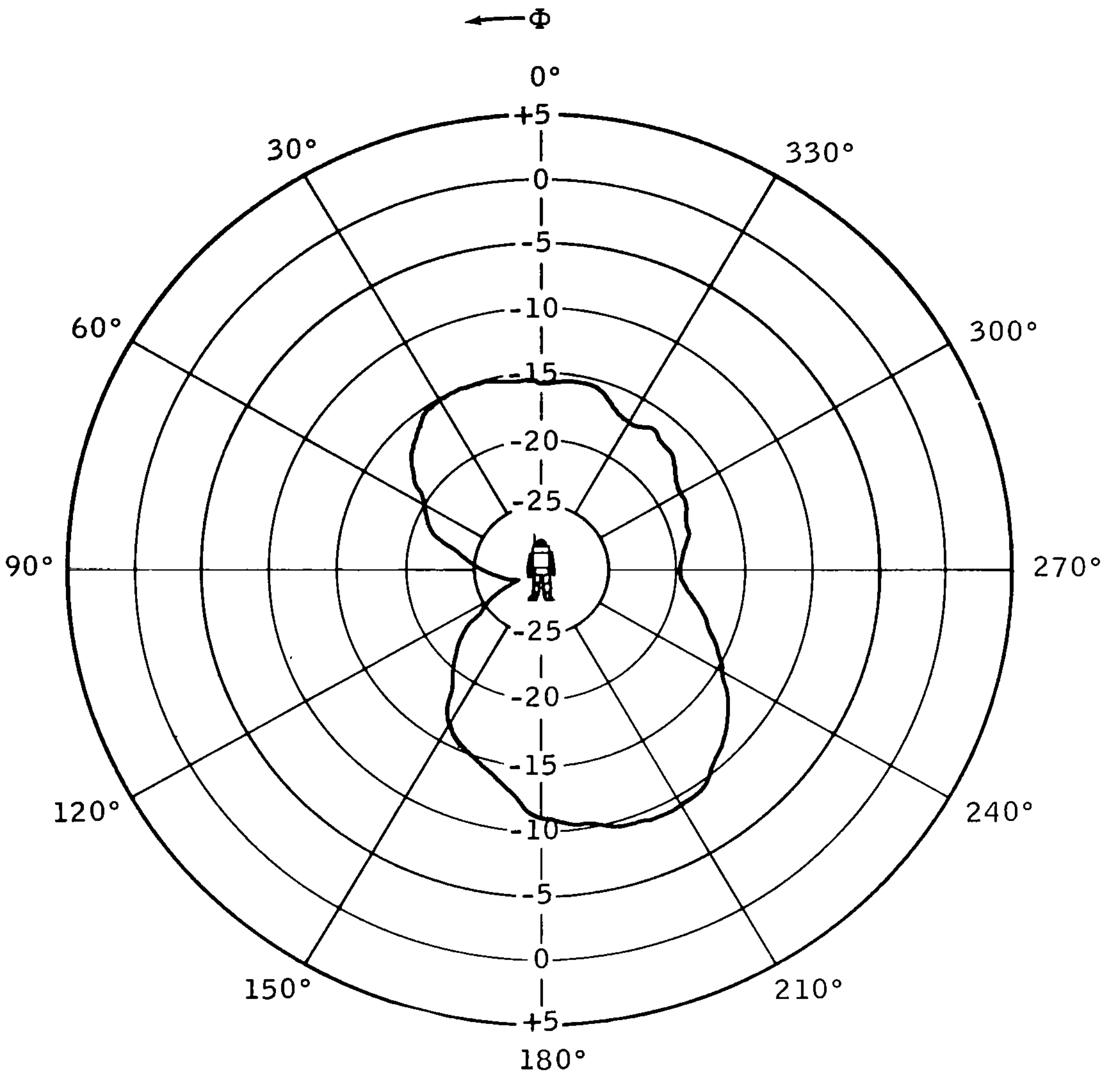
Figure 6. - Continued.



The gains are referenced to a perfect isotropic level of vertical-linear polarization established at the 6-foot standing height by substitution of a reference dipole.

(h) Bending-over position and f = 296.8 MHz.

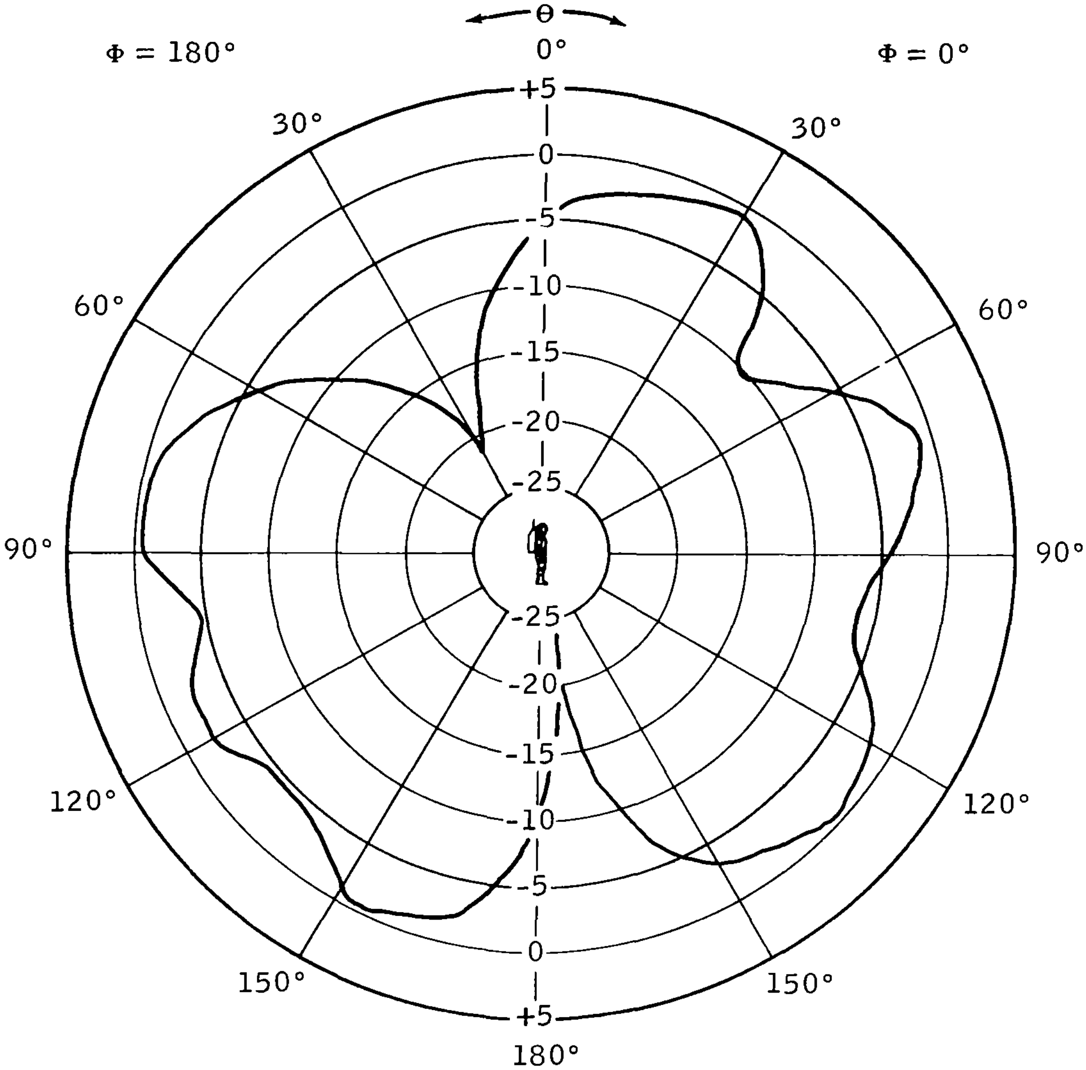
Figure 6. - Continued.



The gains are referenced to a perfect isotropic level of vertical-linear polarization established at the 6-foot standing height by substitution of a reference dipole.

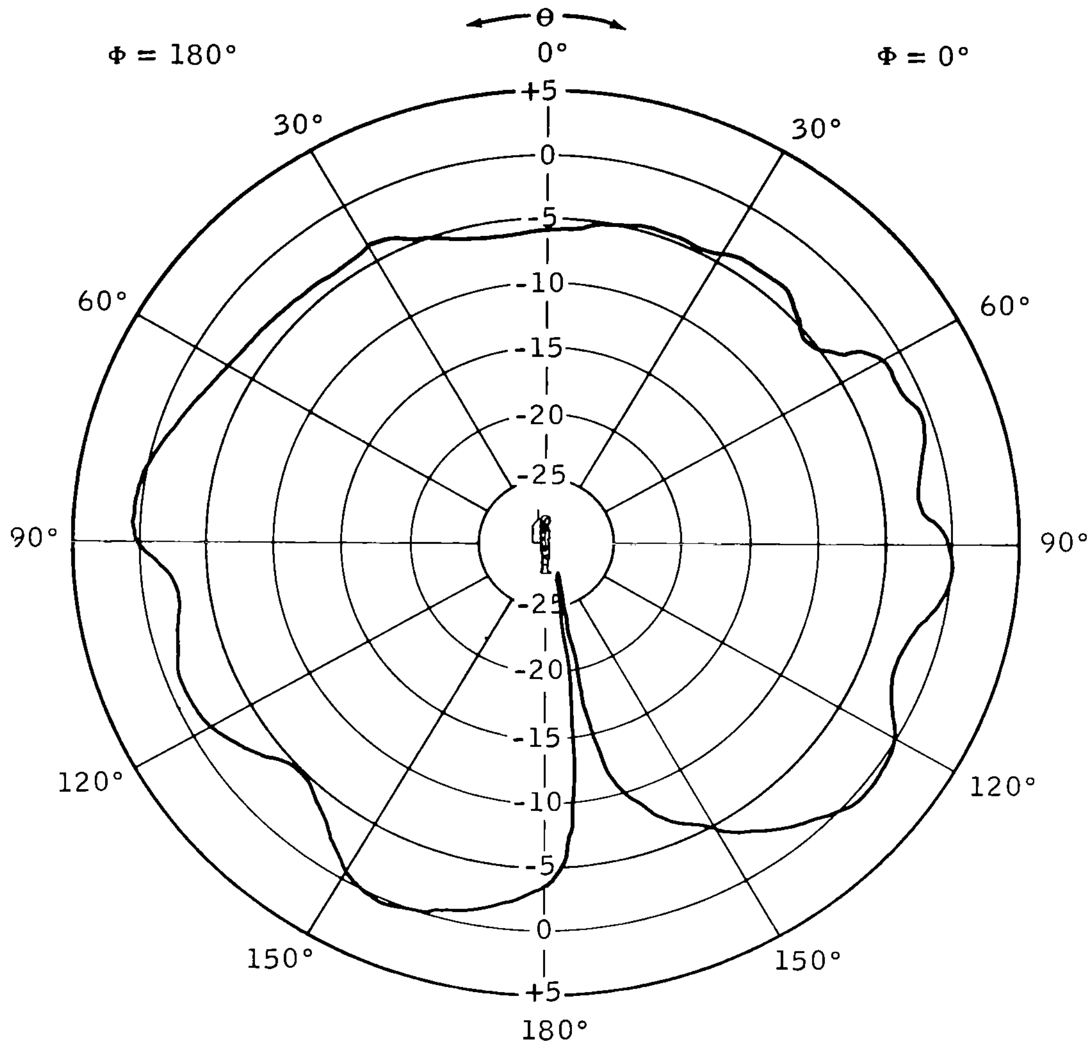
(i) Lying-face-down position and f = 296.8 MHz.

Figure 6. - Concluded.



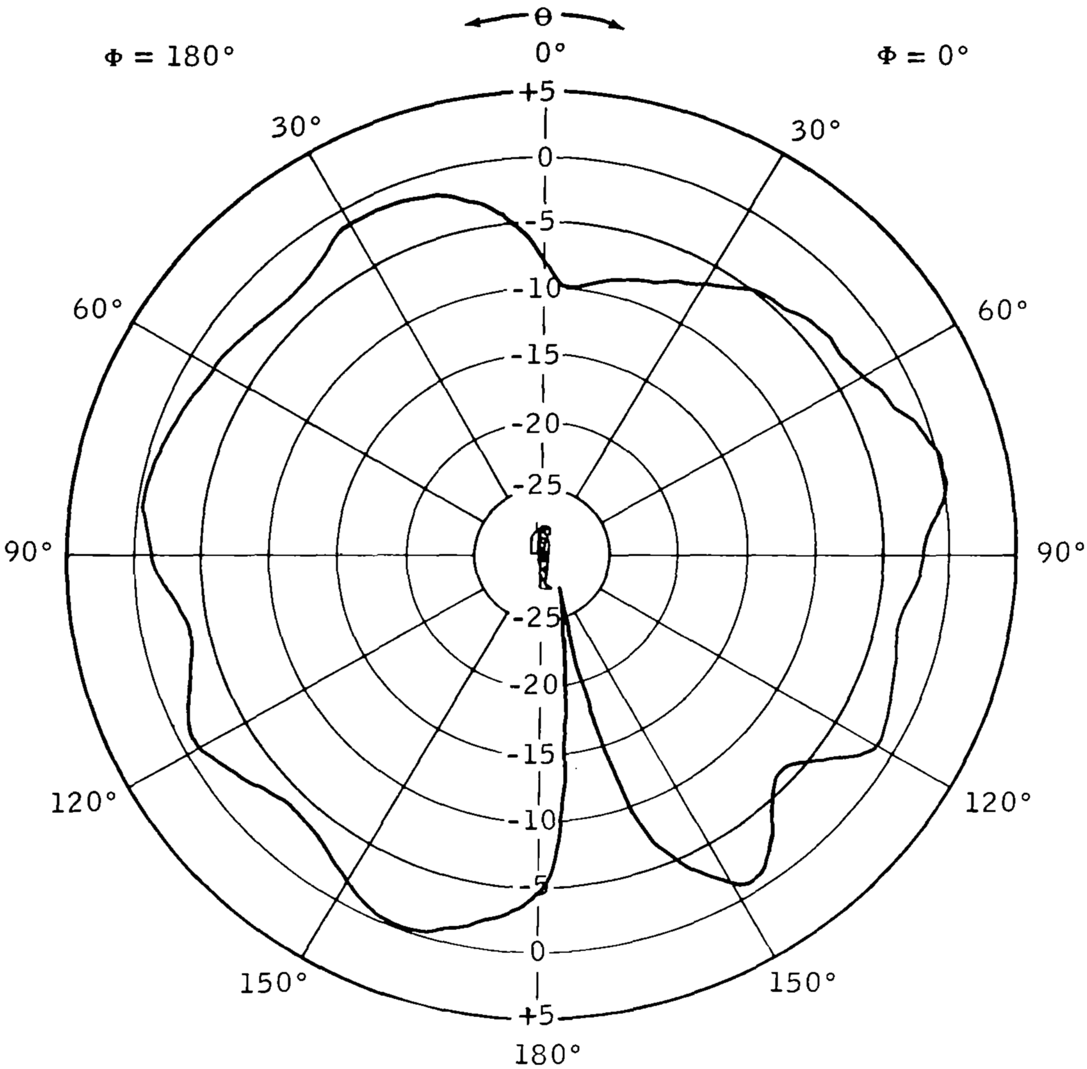
(a) f = 259.7 MHz.

Figure 7. - Free-space Apollo astronaut monopole antenna pattern. The gains are referenced to a perfect isotropic level of vertical-linear polarization established by substitution of a standard-gain dipole.



(b) f = 279.0 MHz.

Figure 7. - Continued.



(c) f = 296.8 MHz.

Figure 7. - Concluded.

NASA-Langley, 1969 — 7 S-200