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L-band Mobile Terminal Antennas for Helicopters

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ABSTRACT

The feasibility of using a low gain antenna (LGA) as a mobile terminal antenna for helicopter is described in this paper. The objectives are (1) to select the lowest cost antenna system which can be easily mounted on a helicopter and capable of communicating with a satellite, and (2) to determine the best antenna position on the helicopter to mitigate the signal blockage due to rotor blades and the multipath effect from the helicopter's body. The omni-directional low gain antenna (LGA) is selected because it is simple, reliable and low cost. The helix antenna is selected among the many LGAs, because it is the most economical one and has the widest elevation beamwidth. Both 2-arm and 4-arm helices are studied experimentally to determine the antenna's performance and the scattering effects from the helicopter's body. It is found that the LGA should be located near the tail section and at least 8" above the helicopter.

INTRODUCTION

Helicopter satellite communication (H-SATCOM) is of current concern, since it has myriad applications, such as, emergency and rescue missions, off-shore drilling, fire fighting, rapid access, passenger transportation, etc. For example, the Norwegian air traffic controllers (ATCs) are monitoring helicopter trips across the North Sea to oil platforms using position data sent automatically from the helicopters to ATCs via the International Maritime Satellite (Inmarsat) [1].

Jet Propulsion Laboratory (JPL), under a contract with the Federal Aviation Administration (FAA), is conducting a study of implementing a very low-cost, small-size, light-weight, real-time communication system specifically for H-SATCOM. In this paper, the feasibility of using LGAs for H-SATCOM is studied. Here the helicopter's banking angle is assumed to be ± 60° and the satellite is the Inmarsat or American Mobile Satellite Corporation (AMSC) or the Low Earth Orbit (LEO) IRIDIUM satellite. The requirements for the helicopter antennas are (1) complying with industry standards, e.g., ARINC 741 and Inmarsat LGA's specs for aeronautical mobile terminals [2], (2) providing a 0 dBic gain in 360° azimuthal and from zenith to 40° below horizon, (3) the transmit and receive frequencies being 1.62-1.67 and 1.53-1.56 GHz, respectively, the transmit power being 19.2 watts, (4) the VSWR being 1.5:1, (5) small-size, (6) light-weight, and (7) low-cost.

There are two unique technical challenges in the determination of the best helicopter antenna location. First is the

a-8

periodic signal fading caused by the helicopter's rotor blades. Second problem is the multipath caused by the scattering from the complicated shape of the helicopter body. Thus the antenna study objectives are (1) to select the low-cost, light-weight, and small-size antenna system for H-SATCOM, and (2) to determine the best antenna position on the helicopter to minimize the signal blockage due to rotor blades and the multipath effect from the helicopter's body. The study results are summarized in the following sections.

ANTENNA SELECTION

To ensure that all the antenna options are considered, the LGAs, the steerable medium-gain antennas [3] and high gain reflector antennas [4] are all included in this exhaustive survey. Both JPL and Antenna Industry publications in this specific application were studied. The high gain (≥ 20 dB) reflector antennas in L-band are usually very large in size (at least 5' in diameter and 1.25' in height) and heavy in weight. In addition, a bulky and expensive tracking system is needed to steer this reflector antenna beam to the satellite direction. Thus it is not suitable for helicopter use.

In general, the medium-gain antennas (including mechanically and electronically steered arrays [3]) are more expensive and less reliable than a low gain antenna due to the fact that an additional tracking system is required to steer the narrow antenna beam to the satellite direction. However, the omni-directional LGAs, as summarized in TABLE 1, are simple, reliable and low cost. Furthermore, the low-gain antennas are typically ten times smaller than the medium-gain antennas. This makes the mounting of the antenna on the helicopter relatively easier. Therefore, the low gain antennas are selected for the H-SATCOM.

Figure 1 shows a 4-arm helix (volute) antenna [5], which gives a cardioid pattern as depicted in Figure 2. Figure 3 shows a donut shaped pattern of a 4-arm conical spiral antenna [6]. Note that one can change the shape, size or pitch angle of a crossed dipole or helix antenna to optimize the gain in the desired directions. The 2-arm helix and the crossed drooping dipole antennas have the widest bandwidth (covering both the transmit and receive frequencies). The 4-arm helix antenna is bandwidth limited and hence requires two antennas for uplink and downlink. But it is attractive since it only costs about \$20. Since the helix antenna has the lowest cost, it is selected for the helicopter use. It is also possible to use multiple antennas or antennas in conjunction with a gyro or compass to compensate for the helicopter's maneuvers. However, due to cost and complexity it is desirable to have one or two antennas without a tracking system.

HELIX ANTENNA TEST RESULTS

Several off-the-shelf helix antennas were tested in an out-door far-field range. Figures 4 and 5 are the measured radiation pattern of a 4-arm helix antenna without and with a 23" by 23" ground plane, respectively. Figure 6 shows the severe pattern distortion as the helix antenna is placed 4" above the ground plane. Figure 7 shows the measured 2-arm helix antenna at 1.5754 GHz. From this test data, we know that this helix antenna has about 2.1 dBic peak gain, 5 dB axial ratio above horizon, and 140° half-power beamwidth. It seems that this antenna is designed to have optimized circular polarizations at 45° cone angle. The measured helix antenna performances are summarized in TABLE 2. Note that several minor discrepancies are observed as compared to TABLE 1. First, for the 4-arm helix antenna, the peak gain is about 0.8 dB lower and the half-power beamwidth (HPBW) is about 10° smaller. For the 2-arm helix antenna, the HPBW is about 20° smaller and the axial ratio is about one dB worse. These minor discrepancies may be attributed to the measurement tolerance and uncertainty. This also implies that extra link margin should be considered for the H-SATCOM system design. The helix antenna should also be placed at least 8" away from the helicopter in order to minimize the ground plane effects.

CONCLUSION and RECOMMENDATION

The helix antenna is selected for H-SATCOM, since it is small-size, light-weight, and low-cost. Several off-the-shelf helix antennas were also tested. None of these antennas will remotely meet the H-SATCOM antenna requirements. But one can change the shape, size, or pitch angle of the helix antenna to meet the requirements. The 0 dBic elevation beamwidth of a single helix antenna is 140°. Thus two helix antennas are needed to provide a 260° coverage. Since the helix antenna's radiation pattern is very dependent on the nearby scattering objects, it is appropriate to conduct a scale model test (or full sized test) and a numerical study to precisely determine the blockage effect of the rotor blades and the helicopter body. The rationale for doing this task is that via the scale model testing we can efficiently determine the best antenna position and performance on the helicopter for SATCOM and also validate the numerical modeling software. Whenever a different helicopter or antenna is superimposed, running the computer model is the most efficient and cost-effective way to provide the SATCOM system designer the necessary and accurate antenna performance data.

ACKNOWLEDGEMENT

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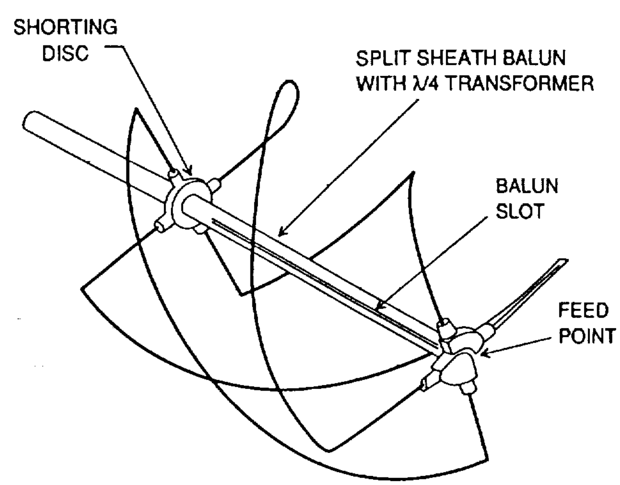

Fig. 1 4-arm helix (volute) antenna configuration

TABLE 1. L-band mobile antenna summary

Antenna Type[a]	Size (cm)		Gain (dB)	Band-width (%)	HPBW (°)	Axial Ratio (dB)	Beam (pattern) Shape	Cost ($/unit)[b]
	HT	Dia.						
Mechanically Steered Array							Steered Beam in AZ	
1.Yagi Array	3.8	53	≥ 10	6.25	40	4		450
2.Tilt Array	15	51	≥ 10	6.25	40	3		600
Electronically Steered Array							Steered Beam in Both AZ and EL	
1.Ball	3.3	61	≥ 8	6.25	40	4		1600
2.Teledyne	1.8	54	≥ 8	6.25	40	4		1800
Low-Gain Omni								
1.Crossed Dipole	12	8	≥ 4	25	100	7	Cardioid/Donut	400
2.Helix (2-arm)	15.2	5.1	2	28	160	4	Cardioid/Donut	150
3.Helix (4-arm)	9	5	4.5	1.3	150	4	Cardioid/Donut	20
4.Conical Spiral (2-arm)	14	6.9	3.8	6.25	160	4	Cardioid	300
5.Conical Spiral (4-arm)	15.7	12.9	4.5	6.25	40	4.5	Donut	400
6.Cavity Backed Slot	0.8	8.3	2	6.25	120	4	Cardioid	1451

a. All the antennas are right-hand circularly polarized.
b. The cost of each antenna unit is a ROM cost based on producing 10,000 units per year over a five-year period.

TABLE 2. Summary of helix antenna's performances

Antenna Type	Frequency GHz	Axial Ratio dB	Bandwidth GHz	Peak Gain dB	HPBW degree
4-arm Helix	1.57	4	0.06	3.7	140
2-arm Helix	1.62	5	0.24	2.1	140

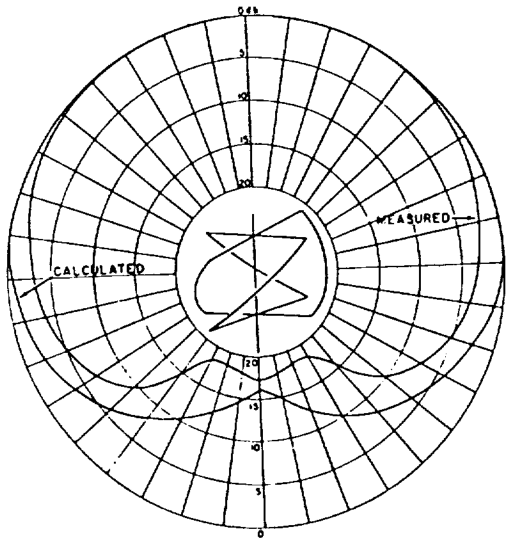

Fig.2 Typical cardioid pattern

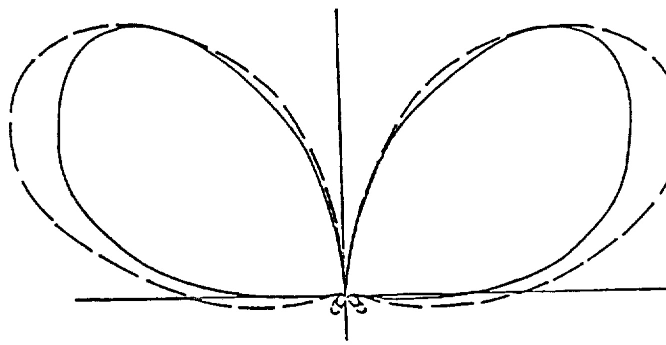

Fig. 3 Typical donut shaped pattern of conical spiral antenna

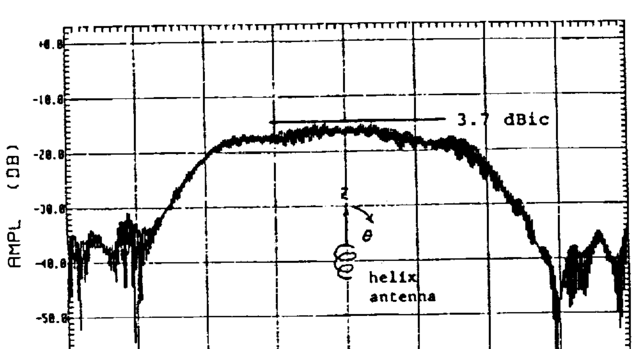

Fig.4 Measured 4-arm helix pattern
No ground plane

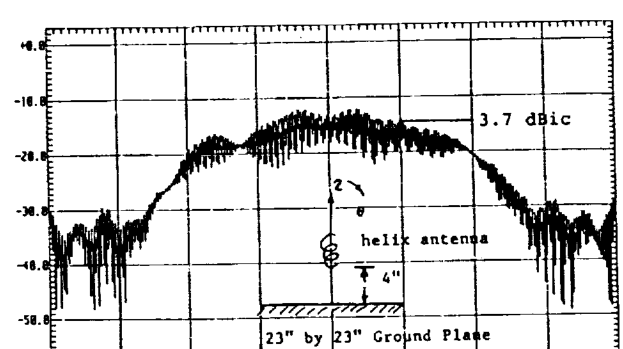

Fig.5 Measured 4-arm helix pattern
with ground plane

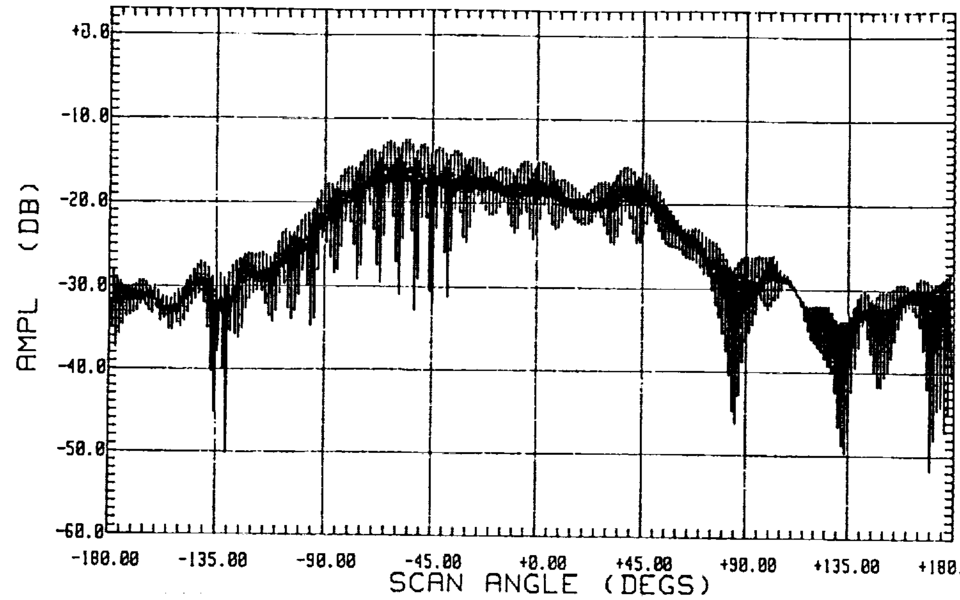

Fig. 6 Measured 4-arm helix antenna pattern at 1.575 GHz antenna right above the finite ground plane

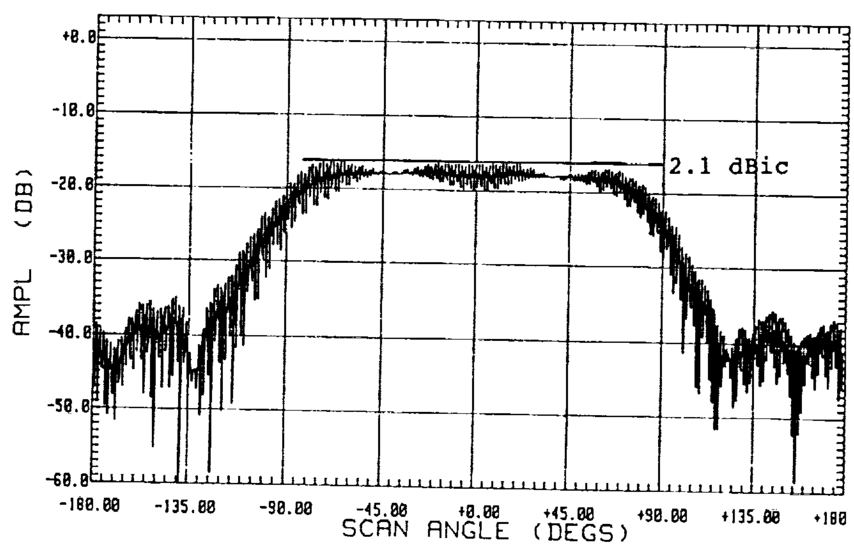

Fig. 7 Measured 2-arm helix antenna pattern