# Broadband circularly polarized antennas for UHF SATCOM

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## Abstract

Novel circularly polarized (CP) antenna configurations derived from Moxon type antenna (bent dipole element over a ground plane) for broadband UHF SATCOM applications. A sequence of topologies starting from a single vertical element to two vertical elements of the Moxon arms, then widened strip arm elements were studied. Further, arms were widened to bowtie structures with bents at $90^{0}$ for achieving broadband operation. Bowtie elements were further split and optimized at a certain angle to achieve wider bandwidth. The logic in this evolution was to obtain highest possible gain based on Fano-Chu limits, which suggests that higher gain can be achieved in an electrically small antenna with maximized metallization in the structure that fill the volume. Circular polarization is obtained by two Moxon based cross elements that are fed through a hybrid $90^{0}$ quadrature coupler. For the antennas that are prototyped, return loss S11 measurements were performed, and gains are simulated using HFSS. For the band of 225-400 MHz, antenna gain varies between 8-12 dB, and S11 is measured to be below 10 dB. Fabricated antennas coupled to a hybrid coupler yielded excellent bandwidths, low cross-polarization and low back lobes on the finite ground planes.

## 1. Introduction

Wide band requirement of modern communication applications on airborne and ground platforms at HF, VHF and UHF bands require antenna specifications such as high forward gain, high cross-polarization, low back lobe radiation, compact size and low cost [1]-[2]. One of the widely used SATCOM antennas is the conventional eggbeater antenna consisting of two cross circular loops coupled to a hybrid quadrature coupler. Antennas proposed and developed here are based on Moxon antenna [3] which is one of the favorite antennas among the amateur radio hobbyists. Moxon antenna consists of a bent dipole over the ground reflector which produces outstanding front to back ratio of radiated power, good match over relatively wide band and lower elevation height. In essence, it is a two element Yagi-Uda antenna. Cross-Moxon antennas fed through a hybrid quadrature coupler are used to obtain right hand circular polarization for possible use as a SATCOM antenna. Extending the width of the strip of the dipole elements lead to wider band and improved cross-polarization ratio. Further widening strips into bowtie and introducing splits in these elements lead to further improvements in performance. Finally split bowtie elements with oblique angle lead to optimized performance close to Fano-Chu limits [4] obtainable by a small antenna with maximized metallic surfaces in a given volume. Cross-Moxon configuration is pursued as an attractive alternative due to its relatively smaller dimensions compared to a comparable eggbeater antenna.

Moxon type antenna [2] (a bent dipole antenna) is known for its compact size and its directive properties due to the presence of the ground plane. A sketch of one of the bent dipole antennas is shown in Figure 1. The length of the one arm of the dipole is L+W, and the arm is bent toward a ground plane from L distance away from the center of the dipole. The end point of the bent dipole antenna is H away from the ground plane as in Figure 1. The bent dipole is fed from the center of the antenna with a differential input. The RHCP can be obtained simply by placing two dipole bent antennas perpendicular to each other, one in x-z plane, the other in y-z plane and feeding through a hybrid $90^{0}$ quadrature coupler .

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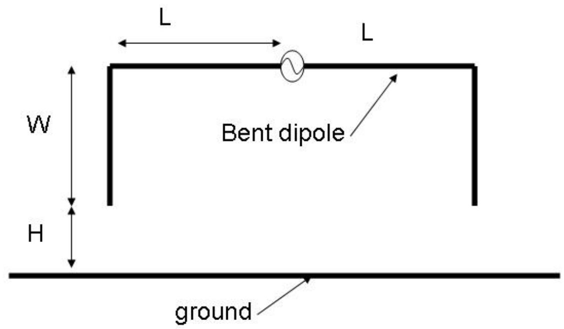
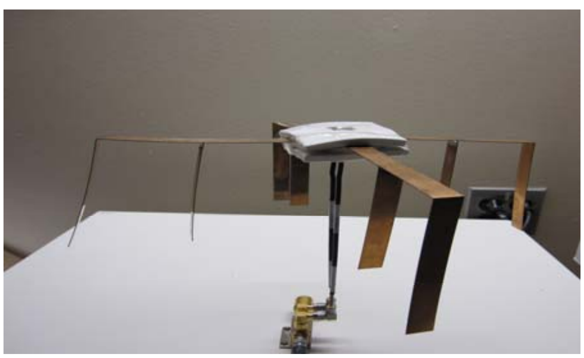



**Figure 1.** Bent dipole antenna over a ground plane

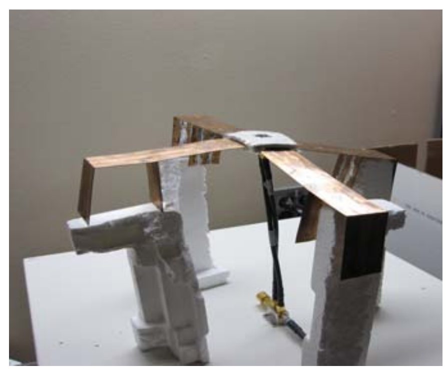
The rest of the paper is organized as follows: in section 2, different antennas that are simulated and measured will be explained in details, in section 3, simulation and measurements results will be shown, finally, the paper will be concluded.

## 2. Prototype Antenna topologies

For broadband operation in VHF band, three different prototype antennas were fabricated and measured. The first of these antennas are the double vertical narrow element cross Moxon antenna as shown in Figure 2(a), resulting in a height of 18 cm and maximum horizontal length of approximately 24 cm, width of the strips is 1.25 cm. Antenna is fed through a quadrature coupler (MINICIRCUITS ZX10Q-2-3+) in the frequency range of 220-470 MHz.



a) Prototype double vertical narrow element



(b) double vertical widened element

**Figure 2**. Cross-Moxon antenna.

For broader bandwidth operation, similar to a thick dipole, the vertical element cross Maxon antenna element width is doubled as seen in the prototype antenna of Figure 2(b).

## 4. Simulation and Measurement Results

The electromagnetic simulations are performed using HFSS (for antenna) and ADS (matching circuit) software tools. For the simulations, the geometrical parameters are chosen as follows to obtain good RHCP properties as well as good matching.

W – length of vertical arms – 126.5 mm ;
L – length of horizontal arms – 138.5 mm ;
H – distance from the ground plane – 12mm
Cross sectional area of the antenna is 2cmX2mm

The ground plane is finite and its dimensions are 4L X 4L. The power handling capability has not been taken into consideration for simulations. The material for the antenna conductor is chosen as copper. The two dipole antennas are fed by a 90 degree phase shift from the two lumped ports. After optimized simulation results, antennas are prototyped and measurements are taken. For the double vertical Moxon elements, the S11 measurement is shown together in Figure 3 with the S11 of an egg-beater antenna which is commonly used antenna for UHF SATCOM applications. S11 is below 10 dB within the bandwidth of 200 MHz centered at 300 MHz.

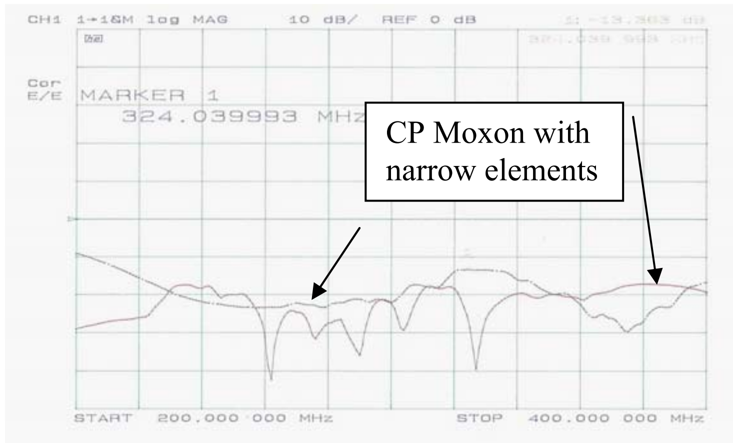



Figure 3. Measured SWR of the double vertical narrow element cross -Moxon antenna at its input terminals of the hybrid coupler. The lower curve belongs to the commercial eggbeater antenna.

The outcome the widened double vertical element cross Maxon antenna yielded slightly wider bandwidth and lower SWR at its input port of the hybrid quadrature coupler. S11 is below 12 dB within the band of 200-400 MHz. Simulated cross polarization has been significantly increased compared to the commercial eggbeater antenna.


**Figure 4.** Measured SWR of the bent bowtie Maxon antenna at its input terminals of the hybrid coupler. The lower curve belongs to the commercial eggbeater antenna.

The outcome of the bowtie element cross Maxon antenna yielded slightly wider bandwidth and lower SWR at its input port as seen in Figure 4. S11 is below 15 dB with in the band of 200-400 MHz. Simulated cross polarization has been improved compared to the one and two vertical element Moxon antenna.

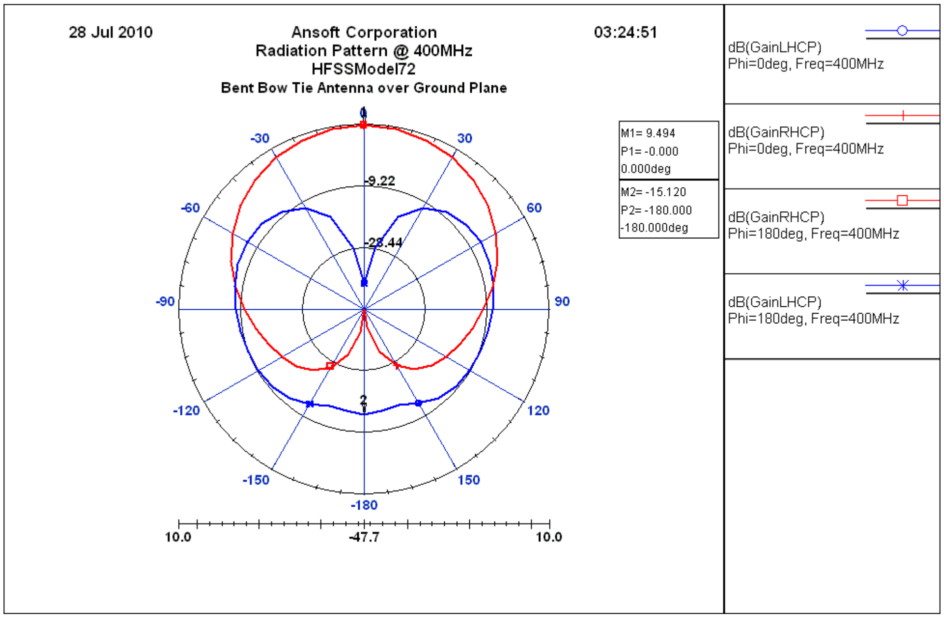



**Figure 5.** Typical radiation pattern of the bow tie antenna at 400 MHz.

Using HFSS version 12.1, antenna radiation patterns are simulated, and a typical radiation pattern for RH and LH polarizations for the bow tie antenna are given in Figure 5. The bow tie antenna is RH circularly polarized within 60 degree from the zenith. At the conference, measured radiation patterns will be presented. In Table 1, simulated gains are given for different frequencies. Max gain of 12.6 dB is obtained at 240 MHz, at 400 MHz gain drops to 9.5 dB.

**Table 1.** Maximum RHCP and LHCP antenna gains

| Frequency (MHz) | Max Gain (dB – RHCP) | Max Gain (dB – LHCP) |
|---|---|---|
| 240 | 12.6 | 0.9 |
| 280 | 8.2 | -5.8 |
| 310 | 7.4 | -8.7 |
| 340 | 8.1 | -10.8 |
| 380 | 9.1 | -14.6 |
| 400 | 9.5 | -15.1 |

## 5. Conclusion

Novel circularly polarized (CP) antenna configurations based on Moxon type antenna (bent dipole element over a ground plane) are presented for broadband UHF SATCOM applications. Two vertical elements of the Moxon arms, widened strip arm elements, bow tie arm structures with bents at $90^0$ for achieving broadband operation are simulated, and measured. For the antennas that are prototyped, return loss S11 measurements were performed, and gains are simulated using HFSS. For the band of 225-400 MHz, antennas have reasonable CP gain and can be used for UHF SATCOM band. Also, bow tie antenna physical structure is most suitable to comply with aerodynamic structure of a radome that can be placed on a body of a helicopter or fixed wing aircraft.

## 6. References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