Broadband Circularly Polarized Moxon Based Antennae for RFID and GPS

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Abstract-Novel circularly polarized (CP) VHF SATCOM antenna which was based on Moxon antenna (bent dipole element over a ground plane) has been extended for RFID and GPS 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 investigated to understand the effects on impedance match over the widened bandwidth. The logic in this evolution was to obtain maximized gain based on Fano-Chu limits, which suggests that more metallization in the radiating configuration that fill the volume would yield higher gain for electrically small antenna. Extending the width of the strip of the equivalent dipole elements lead to a wider bandwidth and improved cross-polarization ratio. Furthermore, splitting the tapered bow tie elements increased the volume filled with radiating elements leading to improved overall performance. Ultimately extended bends at the tip of the tapered sections parallel to the ground plane helped to improve overall performance. In overall, the antenna presented here produced lower physical height, higher gain, wider bandwidth, better cross-polarization and lower back lobe radiation compared to commercial counterparts such as an eggbeater currently used in SATCOM practice as well as similar antennas in RFID and GPS applications.
Here, the concept is extended to cover RFID (850-1050 MHz) and GPS (centered at 1227 and 1575 MHz) bands leading to new applications at a significant cost and size reductions and much improved performance. Prototype antennas were built based on HFSS simulations yielded better than -25 dB return loss. During simulations attention was paid to identify the effects of individual antenna elements as an optimization parameter on the overall input impedance matching over the extended bandwidth. Simulated and measured results yielded higher than industrial counterpart antenna gain, bandwidth and cross-polarization for much reduced physical dimensions.

1. INTRODUCTION

Novel circularly polarized (CP) VHF SATCOM antenna[1] which was based on Moxon antenna [2](bent dipole element over a ground plane) has been extended for RFID and GPS applications. For RFID mobile applications [3], tag reader antenna is required to have high performance including a broadband operation, circular polarization as well as a large angular coverage from horizon to zenith. For systems at these frequencies, wavelength could be on the order of third to quarter of a meter and conventional antennas may be ''too big'' for commercial use. For GPS applications [4], antennas are required to have very precise narrow band performance at specific frequency bands (L1 and L2 bands). Novel tag reader RFID antenna and another dual band GPS antenna based on extended Moxon antenna were proposed. Moxon antenna is basically a two-element Yagi-Uda antenna [5], with a bent dipole element to reduce its height and is commonly preferred antenna for HAM operators due to its size, forward gain and wide band impedance match. A systematic sequence of topologies starting from a single vertical element to two cross vertical elements of the Moxon arms fed through a hybrid coupler to achieve Circular Polarization is implemented. Then widened strip arm elements were investigated to understand the effects on widening the bandwidth. The logic in this evolution was to obtain maximized gain based on Fano-Chu limits, which suggests that more metallization in the radiating configuration that fills the volume would yield higher gain for electrically small antenna[6]-[7]. Extending the width of the strip into tapered shape and splitting of the equivalent dipole elements with additional bends at the extended tips of these tapered bowtie [8] arms lead to a wider bandwidth and improved cross-polarization ratio. In overall, the antenna presented hereafter experimental measurements produced lower physical height, higher gain, wider bandwidth, cross-polarization and lower back lobe radiation compared to commercial counterparts such as an eggbeater currently used in SATCOM practice as well as similar antennas in RFID and GPS applications.

2. DESIGN AND OPTIMIZATION PARAMETERS OF THE MOXON BASED ANTENNA

The proposed antenna consists of two bent Moxon type split bowtie antennas. The two bent antennas are located perpendicular to each other as shown in Figure 1and are fed at the center via differential input through a hybrid coupler to produce Right Hand Circular Polarization (RHCP). An expanded view of an arm (petal) is shown in Figure 2 marked with numbers to identify the optimization parameters used in numerical simulations.

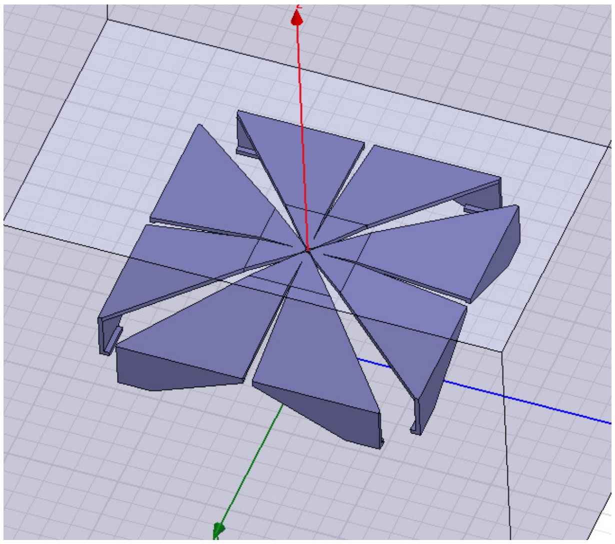

Figure 1. Moxon based RFID tag reader antenna in 3D space.

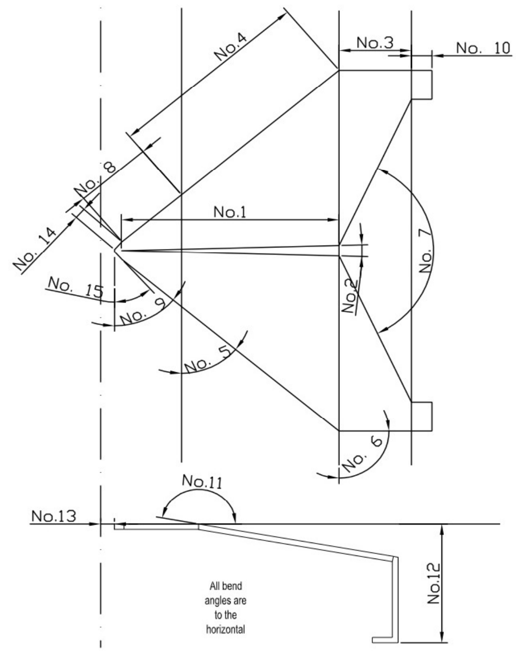

Figure 2. Single triangular shaped antenna arm.

The detailed optimization observations are given in Table 1 based on numerical simulations carried out using ANSOFT High Frequency Structure Simulator (HFSS).

III. MOXON BASED RFID TAG READER ANTENNA

RFID tag reader antenna is designed to operate in 850MHz to 1050MHz range. Characteristic dimensions of a single triangular shaped antenna conductor are shown on Fig. 4. Assembled antenna over a ground plane is shown on Fig. 5. The Return Loss of the RFID antenna is simulated (Fig. 6) and compared to measured performance of the prototype (Fig. 7). RFID antenna has simulated S11 3dB range of 710 MHz to 1200 MHz. Measured S11 is better then 10dB in 800MHz to 1180MHz. Antenna gain is simulated to be approximately 7dB and front to rear ratio is –15dB. When assembled antenna is measured over a small (compared to the size of the antenna) ground plane and compared with a commercially available RFID of known gain, the measured gain of the Moxon type RFID antenna (4Xin area than the antenna developed here) can be judged to be around 15dB to 17dB.

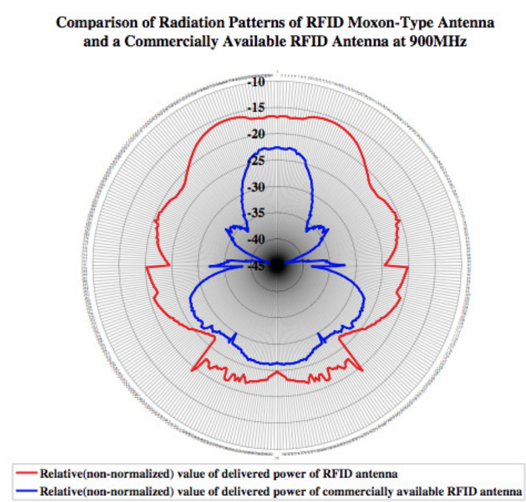

Figure 3: RFID measured antenna pattern comparison.

No:	Description	RFID	GPS
1	Wedge cutout length	Moving wedge tip closer to the Z axis, effectively makes the first section of the wedge◄►, shifts central frequency ▼ and ►◄BW	
2	Wedge cutout spread angle	►◄the angle, i.e. sharpening the wedge cutout, ◄► BW and shifts central frequency (or resonance) ▲	
3	Vertical length Changing the length ◄►	Low resonance point ▼ in frequency but ▲in S11, high resonance point ▼ in frequency and ▼ in S11. Total bandwidth decreases.	
	►◄	Low resonance point ▲ in frequency but ▼in S11, high resonance point ▲in frequency and ▲in S11. Total bandwidth increases.	
4	Length of the first bend ◄►	Low resonance point ▼ in frequency but ▲in S11, high resonance point ▼in frequency and ▲in S11. Total BW ▲	Low resonance point ▼ in frequency but ▲in S11, high resonance point ▼in frequency and ▲in S11. Total BW▼
	►◄	Low resonance point ▲in frequency but ▼in S11, high resonance point ▲in frequency and ▼in S11. Total BW▼	Low resonance point ▲in frequency but ▼in S11, high resonance point ▲in frequency and ▼in S11. Total BW▲.
5	Outer angle of the first bend Bigger:	Low resonance point ▼ in frequency but ▲in S11, high resonance point ▼in frequency and ▼in S11. Total BW▼	Low resonance point ▲ in frequency but ▼in S11, high resonance point ▼in frequency and ▼in S11. Total BW▼
	Sharpen	Low resonance point ▲in frequency but ▼in S11, high resonance point ▲in frequency and ▲in S11. Total BW ▲.	Low resonance point ▼n frequency but ▲in S11, high resonance point ▲in frequency and ▲in S11. Total BW ▲.
6	Outer angle of the vertical section (90 degrees)	►◄ outer angle of the vertical section, i.e. sharpening the angle, improves Reflection Impedance around lower resonance frequency, while looses some match around higher resonance frequency. No significant loss of bandwidth is observed with sharper outer angle.	
7	Inner angle of the vertical section ◄►	Low resonance point ▼in frequency but ▼in S11, high resonance point ▼in frequency and ▼in S11. Total BW stays	Low resonance point ▲ in frequency but ▼in S11, high resonance point ▼in frequency and ▲in S11. Total BW▼.
	►◄	Low resonance point ▲ in frequency but ▲ in S11, high resonance point ▲in frequency and ▲in S11. Total BW stays.	Low resonance point ▼in frequency but ▲in S11, high resonance point ▲in frequency and ▼in S11. Total BW▲.
8	Horizontal length (no tip) ◄►	Low resonance point ▼ in frequency but▲ in S11, high resonance point▼ in frequency and ▼ S11. Total BW ▼.	
	►◄	Low resonance point▲ in frequency but ▼ S11, high resonance point ▲ in frequency and ▲in S11. Total BW ▲.	
9	Outer angle of the horizontal section◄►	Low resonance point ▲ in frequency but ▼ S11, high resonance point ▼in frequency and ▲ in S11. Total BW▼ .	
	►◄	Low resonance point ▼ in frequency but ▲in S11, high resonance point ▲in frequency and ▼in S11. Total BW▲	

Table 1. Optimization of geometrical parameters in numerical simulations. Only 9 out of 14 parameters used are presented here.(◄► -longer(larger), ►◄- shorter(smaller), ▲-higher (increase), ▼-lower (decrease))

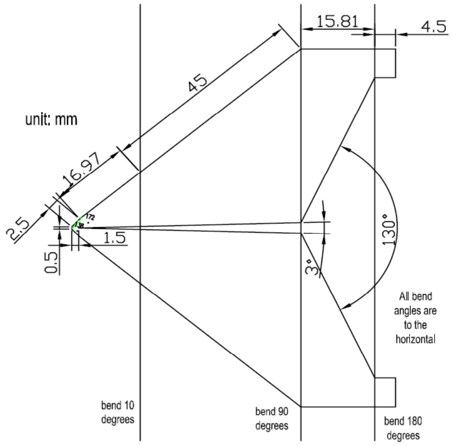

Figure 4: Dimensions of a single triangular shaped RFID tag reader antenna arm.

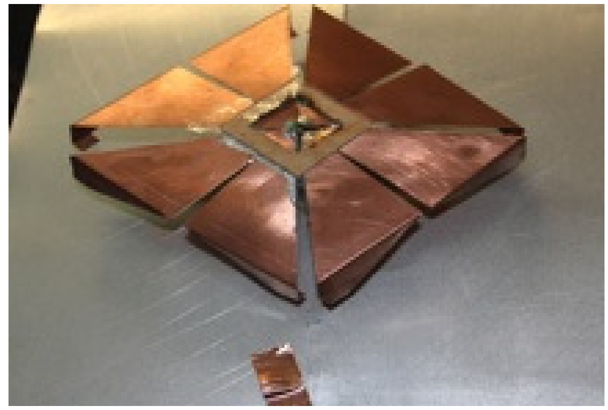

Figure 5: Assembled RFID tag reader antenna over a ground plane.

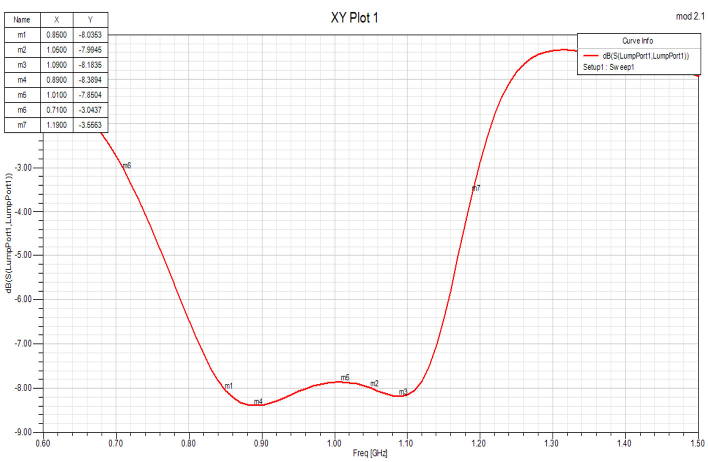

Figure 6: Simulated return loss of the RFID antenna.

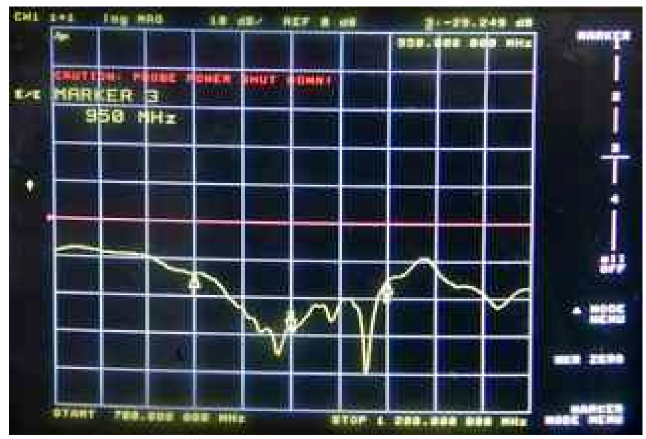

Figure 7: Measured return loss of the RFID antenna.

4 . MOXON BASED GPS ANTENNA

Moxon based type antenna for GPS applications is designed to work in two GPS bands, 1227 +/-10.23 MHz and 1575+/-10.23 MHz. Characteristic dimensions of a single triangular shaped antenna arm are shown in Figure 10. Assembled antenna over a ground plane is shown on Fig. 9. The Return Loss of the GPS antenna is simulated (Fig. 11) and compared to measured performance of the prototype (Fig. 12). GPS antenna has simulated S11 3dB range of. 1000MHz to 1720MHz. Measured S11 is better then 10dB in 1000MHz to 1600MHz and features deep resonances around both bands of interest, where RL is better then –30dB. Antenna gain is simulated to be approximately 6.6dB at 1227MHz and 8.25dB at 1575MHz, while front to rear ratio is better then –14dB. Measured relative power delivered by the antennna is shown on Fig. 8 for both ranges. Higher band shows somewhat lower power then the lower band due to mismatch and alignment issues during the experiment.

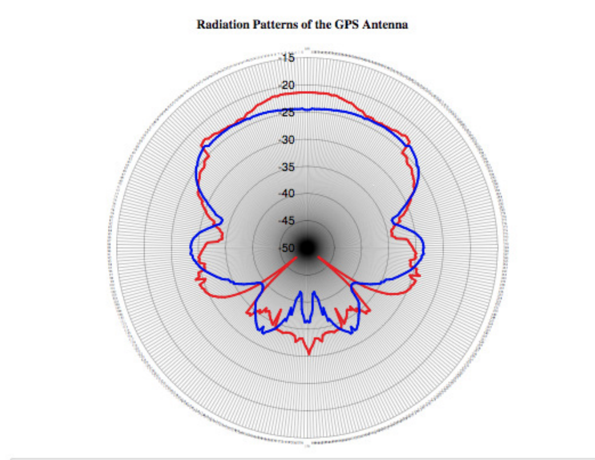

Figure 8: Measured radiation patterns of the GPS antenna at L1 and L2 bands.

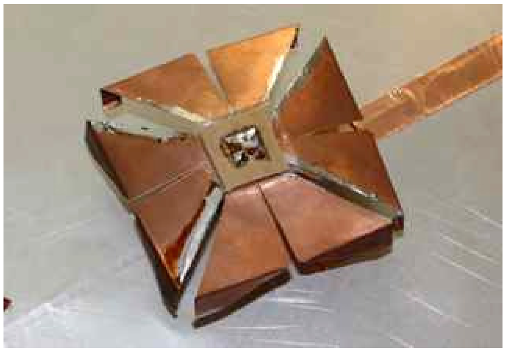

Figure 9**:**Assembled GPS antenna over ground plane

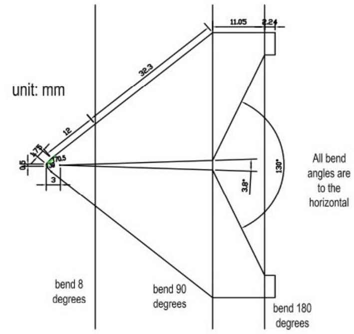

Figure 10**:** Dimensions (in mm)of a single antenna arm.

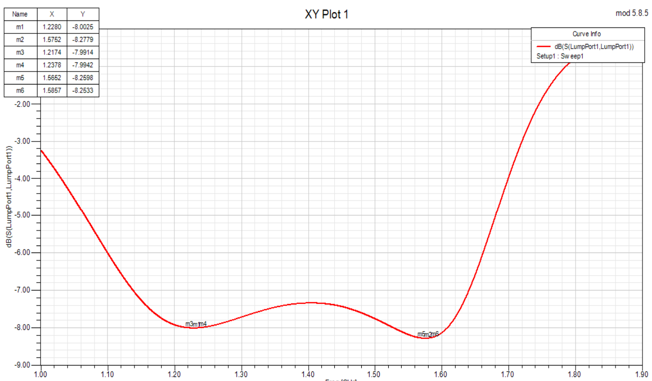

Figure 11**:** Simulated Return Loss of the GPS antenna.

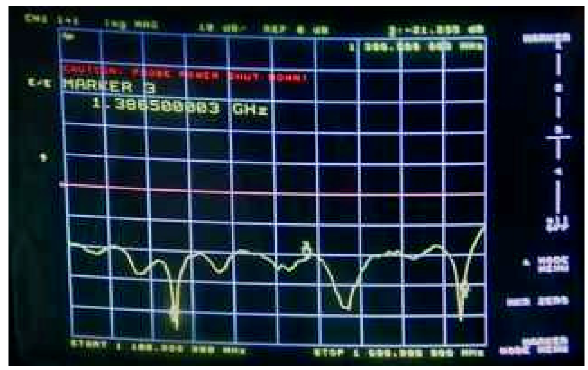

Figure 12: Measured Return Loss of the GPS antenna.

5. CONCLUSIONS

Moxon based RFID and GPS antennas were proposed. Extensive numerical simulations based on optimization of various parameters on the antenna structure were carried out to achieve higher gain, wide band impedance match, high cross-polarization and low profile. Prototype antennas were built and tested confirming good agreements between simulation and experimental results. Furthermore, prototype antennas were compared with commercial counterparts and were observed that RFID tag reader antenna was almost 4 times smaller in physical dimensions for a higher gain of 17 dB. In case of GPS antenna the overall gain was observed to increase for the comparable dimensions.

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