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# Deployable Log-Periodic Dipole Array Antenna for CubeSats

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## Introduction

CubeSats have become increasingly popular ever since the concept of a standardized design for nanosatellites was created at California Polytechnic State University in 1999. The purpose of this standardized design was to reduce cost and development time and lower the barrier of entry to space. The standardization allows both academic and commercial teams to be involved in the design and development of CubeSats without requiring massive funding afforded by space agencies. CubeSats typically operate in Low Earth Orbit (LEO), are lightweight, and can be built using Commercial Off-The-Shelf (COTS) components. Their sizes can vary from 1U (10cm x 10cm x 10cm) up to 12U (20cm x 20cm x 30cm) and weigh around 2.9 lbs per unit. These constraints lead to fundamental limitations in designing the subsystems of the satellite.

One of the main subsystems of the CubeSat that is required for mission success is the communication subsystem. Without wireless communications, no data could be sent to or from the satellite, rendering the CubeSat useless. There are three types of mission critical data that is transmitted or received by the CubeSat. These include telemetry which describes the condition of the satellite, telecommands which are sent from the ground to control the satellite, and payload data such as images or sensor measurements from the satellite. As payloads and instrumentation aboard CubeSats become more complex, higher data transmission rates are necessary to transfer data in real time.

One of the most important components of the communication subsystem is the antenna. Currently most CubeSats typically use patch, slot, dipole and monopole, and reflector antennas [1]. These designs all have their own advantages and disadvantages, but a common disadvantage among them is their narrow bandwidth ranging from 1% to 45% with comparably low gain. Designing a high gain, ultra-wideband antenna to operate in the S band for a larger transmission bandwidth may require a size that exceeds the size constraints of the CubeSat, which will require a deployment mechanism.

In this paper, a log-periodic dipole array (LPDA) is proposed. The main advantages of the LPDA are that it has a low voltage standing wave ratio (VSWR) of less than 2:1 through the operational bandwidth, leading to an ultra-wide bandwidth ($S_{11} < -10$ dB) while still having a high gain of 6-10 dBi. Such an array could be made using bistable composite tape-springs [2]-[4], which are stable in both the rolled and fully deployed position. This would allow the LPDA to be completely rolled up to be stowed for launch, storing tension in the tape-springs which then can be released, deploying the tape-springs into position without use of any motors. A computational electromagnetics software product called FEKO, created by Altair Engineering, is used to simulate and optimize the antenna to test the feasibility of this deployable LPDA design.

## Antenna Design

To achieve a log-periodic dipole array design, initial parameters should be calculated. These include $\tau$ which is the taper rate, $\sigma$ which is mean relative spacing, the desired lower and upper frequencies, diameter of elements of feeder lines, and the input impedance [5]. The directivity of an LPDA is a function of the $\tau$ and $\sigma$ values. $\tau$ values can range anywhere from 0.77 to 0.98 with $\sigma$ values ranging from 0.06 to 0.22. The closer $\tau$ is to 1, the less the element sizes vary. Decreasing the $\tau$ value will reduce the number of elements. For each $\tau$ value, there is an optimum $\sigma$ value which will give the highest directivity and has the smallest side lobes. To demonstrate the feasibility of a deployable LPDA in this study, a $\tau$ value of 0.891 with $\sigma$ value of 0.1639 was chosen to create a smaller antenna that will still operate effectively in the entire S-band which is 2-4 GHz.

MATLAB was used to create a script to take these parameters and calculate the approximate dimensions of the initial LPDA design using the diameter of the tape-springs found in [2] and [4]. For simplicity, the diameter of the antenna elements and boom are kept the same at 0.635 cm as that is the width of the copper element found in the tape-springs and assumed to be rectangular and not curved. The input impedance is set to 50 ohms. From all these parameters, the initial design is created. The simulation does not yet consider the top and bottom layer of the 1.27 cm inch wide quartz fabric that contains the middle 0.635 cm copper alloy.

## Conclusion

The simulation results of the initial design showed that further work is needed to tune the LPDA so that it operates well for the designed frequencies. Despite the $S_{11}$ bandwidth not being satisfactory, the radiation pattern and total realized gain matches expectation. The main challenge is to reduce the impedance mismatch between the LPDA and the input source which should be achievable. Since this study is validating the use of tape-springs found in [2] and [4] as the antenna material, the dimensions of this material are fixed and cannot be adjusted, unless different size tape-springs are sourced that could work more efficiently while being able to compact itself. Other parameters such as dipole lengths, boom spacing, and dipole spacing can be adjusted in an iterative process to achieve a workable design. The goal is to first optimize the single polarized design and then add in a second LPDA orthogonal to the first so that circular polarization can be achieved.

There are several limitations with integration of this design into a CubeSat, such as that for the LPDA to work properly, it must be fed to the side with the shortest elements but this side must also be pointed towards the ground station so it cannot be mounted directly by this side. LPDA designs are also typically connected with a terminating stub at the side with the longest elements, but for higher frequencies this may not be needed. This would also not be easily done here since the nature of the tape-springs means it can only be connected on one side, as the opposite end will be tucked into the rolled-up state. It remains to be determined how the different elements will connect to each other in a way that will let each element deploy in a consecutive fashion without error.

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