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Easy-to-Deploy LC-Loaded Dipole and Monopole Antennas for Cubesat

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***Abstract*—This paper proposes a new approach to reduce weight and complexity of VHF/UHF cubesat antennas by utilizing a dual band antenna, rather than standard two-antenna system routinely implemented in cubesats. Three systems are compared: A standard system with separate transmit/receive dipoles, a dual-band dipole for both transmit and receive and a dual-band monopole, which uses the body of 1U cubesat (10 × 10 × 10cm) as a "groundplane". Additionally it is demonstrated that with appropriate feed the dipole might be used in monopole configuration in case of deployment system malfunction.**

***Index Terms*—small satellite, dual band antenna, VHF, UHF**

I. Introduction

In recent years many cubesats have been launched. Due to their small dimensions they rely on simple antenna structures for the up- and downlink. These structures routinely use amateur radio channels to communicate with the groundstation. The Compass-2 satellite from RWTH Aachen [1] uses S-Band for high-speed communication and a combined VHF/UHF system as a fallback solution for basic telemetry data. In this particular system, a UHF dipole antenna is combined with a VHF monopole antenna. The KNACKSAT mission by King Mongkut's University of Technology Bangkok [2] uses two perpendicular dipole antennas for each frequency band. This cubesat design will act as a reference system in this paper.

Due to mechanical complexity, small space in the launcher and limitations of deployment system there are numerous efforts to simplify the design by using a single antenna. Also minimizing the amount of any mechanical components increases satellite reliability. One exemplary solution is [3], where a single monopole antenna is matched at two different frequencies. This however might have disadvantages on the pattern.

This paper proposes dual-band antennas, loaded with a LC circuit to simplify the design and increase reliability, allowing for a smaller and more lightweight payload, as compared to [1, 2]. The design permits similar input impedances at both frequencies, thus necessitating a single matching circuit. This simplifies the system compared to [3]. Two antennas integrated with a 1U cubesat model are investigated and compared to a standard, dual-antenna configuration. The first antenna is a dual-band λ/2-dipole, the second one is a dual-band λ/4 monopole using the electrically small (< 0.05 λ at VHF) satellite body as a groundplane.

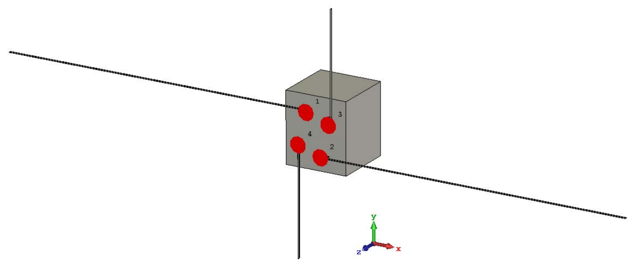

Fig. 1 Model of conventional two antenna configuration

II. Simulation Setup

Three different configurations are compared, first a

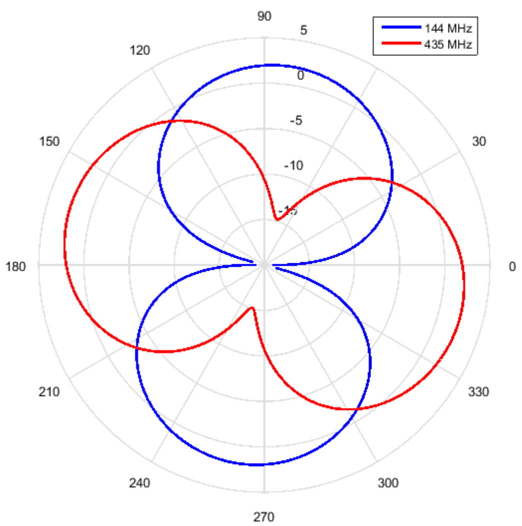

Fig. 2 Simulated gain pattern of conventional two antenna system in *xy*-plane.

conventional two antenna configuration, then a dual-band dipole antenna and lastly a dual-band monopole antenna. In the model cubesat the uplink is in the VHF band at 144 MHz whereas the downlink is in UHF at 435 MHz. Both frequencies are amateur radio bands. The satellite bus is a "single" 1U cubesat with an overall size of 10 × 10 × 10 cm. It is modelled by a brick of perfect conducting metal. All simulations are carried out using the time domain solver of CST Microwave Studio.

III. Conventional Two Antenna System

The conventional reference system uses two separate antennas for uplink and downlink (seen in Fig. 1) which are deployed by a release mechanism and extend due to stiffness of the antenna material. Both antennas are classical λ/2-dipoles with a length of 1 m for VHF uplink and 35.3 cm for UHF downlink. The antennas are positioned perpendicular to each other. The simulated gain patterns are shown in Fig. 2. The cuts are in the *xy*-plane. The characteristic figure-of-eight shape of λ/2-dipole antennas can be clearly seen. The gain of the VHF antenna is 2.02 dBi which is close to the 2.15 dBi expected from a lossless dipole [4]. The UHF antenna shows a slightly higher gain of 2.43 dBi. This is due to the fact, that the antenna terminals are spaced 10 cm apart according to Fig. 1. The maxima of the gain patterns point in the 10°-260° plane for VHF and in the 160°-340° plane for the UHF. In summary, the simulation verifies the system as a feasible solution for a VHF/UHF-satellite communication system.

IV. Dual Band Dipole

The first proposed system utilizes a dipole loaded with

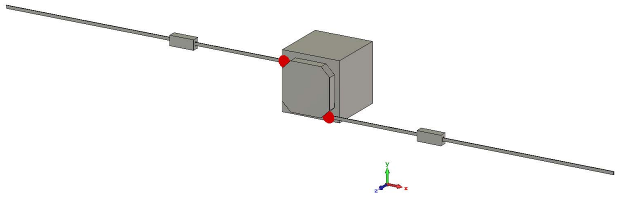

Fig. 3 Model of proposed dual band dipole

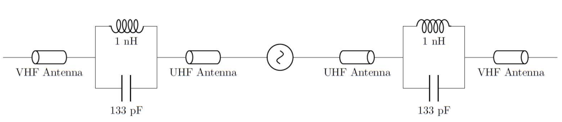

Fig. 4 Circuit schematic of proposed dipole

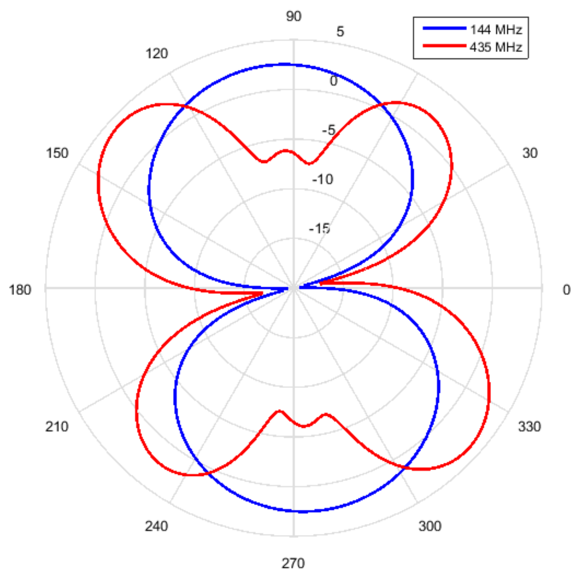

Fig. 5 Simulated Gain Pattern of Proposed Dual Band System

LC-circuit, seen in Fig. 4. The load acts as a notch filter in the UHF band, exciting solely the inner section of the antenna at high frequencies. For VHF operation, the filter is in the passband, thus the full length of the antenna is excited. The length of the outer sections has to be shortened slightly to compensate for the added reactance. The LC load has an inductance of 1 nH and a capacitance of 133 pF. These components are easily available off-the-shelf, as they are used in terrestrial amateur radio antennas [5].

The simulation model used is shown in Fig. 3. The length of the inner arm is 17.65 cm resulting in an antenna length of 35.3 cm for UHF operation. The outer arm has a length of 31.35 cm which together with the inner arm results in a total antenna length of 98 cm for VHF operation. The reflection coefficient is shown in Fig. 9 (red line), demonstrating good impedance match at both frequencies. The resulting patterns are shown in Fig. 5 for the *xy* plane. The gain at 435 MHz (VHF) is 2.59 dBi, which is comparable to the conventional system in Section III and to that of a λ/2-dipole. The UHF-part has a higher maximum gain of 3.91 dBi, with minima of around -8 dB seen for φ = 90° and 270°. This is an effect of the longer arm acting as parasitic element on the antenna, effectively extending the antenna area to 1.4 λ length. The zeros of both patterns are pointing in the 10°-190° plane, which makes both patterns more similar when compared to the reference system.

V. Dual Band Monopole

A dual-band monopole antenna was designed to further reduce the antenna's size. The simulation model is shown in Fig. 6. The values of the inductance and capacitance in the LC-circuit as well as the antenna arm dimensions are the same as described in Section IV. The simulated gain patterns in the *xy* plane are shown in Fig. 8. The gain is 2.14 dBi in the VHF band and 4.35 dBi in the UHF band. Due to lack of a second arm the input impedance has substantially changed requiring a matching circuit, as seen in Fig. 7. The reflection coefficient of the monopole antenna is shown in Fig. 9 (blue curve). The 10 dB bandwidth is 6 MHz for VHF and 30 MHz for UHF, which covers entirely the respective amateur radio bands and is thus sufficient for use in the proposed scenario. Another issue of this antenna configuration is the small groundplane, especially in the VHF band. This has an impact on the pattern, which differs from the "classical" omnidirectional monopole pattern. This asymmetrical pattern has to be accounted for in the overall mission design.

In summary the proposed monopole configuration offers a working and lightweight dual-band antenna with the drawbacks of an asymmetric pattern and the need for a matching network. The system can act as a backup antenna configuration in case of a wrongfully partially-deployed dipole. In this configuration, a switching network disconnects the undeployed dipole arm whereas the deployed arm is connected via the proposed matching network.

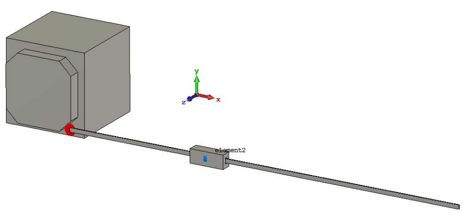

Fig. 6 Model of Proposed Dual Band Monopol

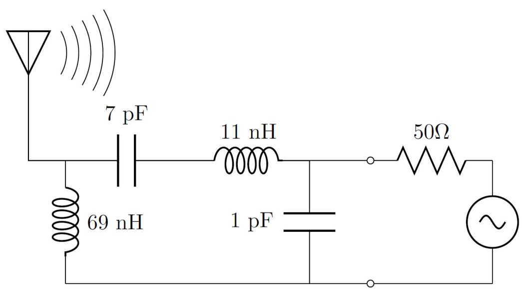

Fig. 7 Matching circuit for monopole

VI. Comparison and Conclusion

The proposed dipole antenna yields similar electrical performance in the VHF band, making both systems comparable in a practical cubesat environment. In the UHF band the conventional system excites a λ/2-dipole pattern. On the other hand the proposed dual-band system has a different pattern with limited area of low radiation (i.e. steeper nulls in the 0°/180° plane) and a notch of -8 dBi in

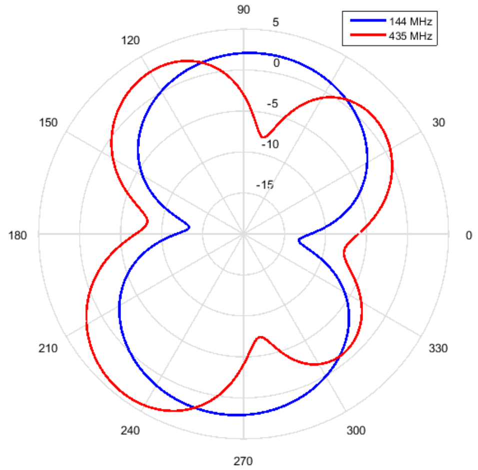

Fig. 8 Simulated gain pattern of the proposed dual band monopole

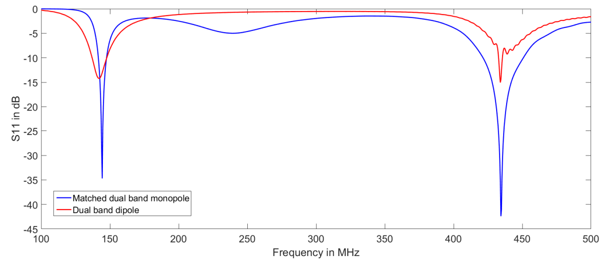

Fig. 9 S-parameters of dual band dipole and matched monopole

the 90°/270° direction. This has to be accounted for in the link budget of the mission, but since most small satellites tend to tumble due to a lack of attitude control, the effect of this different pattern is likely to be negligible.

The proposed monopole system can be used at two frequencies if a matching network is used. Furthermore, the pattern has no longer an axis of symmetry along the antenna's axis. If this change in the pattern is acceptable for the link budget of the mission or an attitude control can be used to point the antenna to the ground station, the system is the smallest compared to the two dipole configurations. An additional application could be a back-up solution, in case one of the dipole's arms has not successfully deployed.

For the two proposed dual-band systems a diplexer will be necessary to decouple up- and downlink channels. In exchange only one release mechanism as well as only one set of cables and connectors is required, which offers an advantage in the mass budget of the satellite mission. This is a crucial parameter for the nano-satellites, which usually is only a secondary payload in the launcher.

In summary the proposed systems offer simple solutions for low cost dual-band antennas in future cubesat missions. They decrease the weight of the satellite and the need for a second release mechanism with the cost of having to design a diplexer. The overall mission design will determine whether such an antenna is a promising solution.

ACKNOWLEDGMENT

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