

A Telemetry Antenna System for Unmanned Air Vehicles

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Abstract— This paper presents a low VSWR high gain telemetry antenna system manufactured for UAVs that provides 360° coverage in the roll plane of the UAV. Proposed telemetry antenna system includes four telemetry antennas, one power divider that has one input and four output terminals which feeds the telemetry antennas with equal magnitude and phase. Proposed high gain telemetry antennas are based on the feeding of the microstrip patch antenna via aperture coupling. Full coverage in the roll plane of the UAV is obtained by using circular array configuration of telemetry antennas. RF power divider is designed by using couple of Wilkinson power dividers with equal line lengths and impedance sections from input terminal to the all four output terminals.

1. INTRODUCTION

Telemetry systems are used for remote data measurement, collection and evaluation of the collected data. Data transfer is done in wireless means. Telemetry systems have been used in several areas such as agriculture, defense, medicine ...etc. Typically, telemetry systems are used on moving objects such as cars, aircrafts and missiles. Airborne telemetry systems are used for remote monitoring the temperature, pressure, vibration and acceleration variations of the UAV during the flight time. The complete structure of a telemetry system includes sensors and transducers, signal conditioners, RF circuits and the transmitter [1].

Telemetry transmitter is mainly composed of telemetry antenna(s) and suitable feeding system of the antenna(s). In the application of flying object which moves very fast and may rotate around its roll axis rapidly, fully coverage in roll plane is required for continuous data transfer. Hence, as shown in Figure 1, telemetry transmitter system requires four telemetry antennas and one RF power divider to feed the antennas with equal magnitude and phase. In this paper, designed antennas and power divider are presented with the simulation and measurement results in the desired frequency range. At the end, VSWR measurement results of the complete telemetry antenna system will be given.

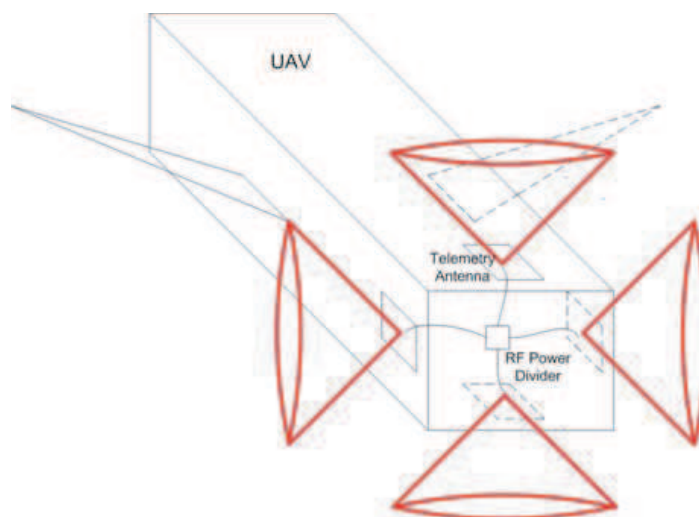


Figure 1: Full coverage in the roll axis of the UAV.

2. TELEMETRY ANTENNA

Proposed telemetry antenna system has four antennas and one RF power divider. Aperture coupled microstrip patch antennas [2] are preferred due to their high gain and wide impedance bandwidth.

Antennas are designed by using HFSS. Antenna optimizations are performed via HFSS Optometric and further optimization is performed with MATLAB Optimization Toolbox. Antennas are printed on ROGERS 4003C substrate due to its low loss characteristics at higher frequencies and its ruggedness. Upper “Air” layer is the patch substrate and the upper ROGERS 4003 layer is used as a radome material. Optimized antenna dimensions are given in Figure 2.

Antenna design and optimization is based on the antenna VSWR value (< 1.5) and the antenna gain (> 8 dBi). Both simulations and measurements are performed on telemetry antennas. Comparison of simulated and measured VSWR and gain values are depicted in Figure 3. Measurements are performed in anechoic chamber of TUBITAK — UEKAE EMC Division with Agilent E8362B Precision Network Analyzer in 2.2–2.4 GHz frequency band. The antenna gain is obtained by using three antenna method and applying Friis [3] equation. Additional measurements are performed to obtain half-power beam width (HPBW), cross-polarization ratio (CPR) and also front-to-back ratio (FBR) at center frequency which is 2.3 GHz and the measurement results are tabulated in Table 1.

3. RF POWER DIVIDER

Telemetry system will consist of four telemetry antennas that should be fed with the same amplitude and the phase. This requires a well designed 1-to-4 power divider to keep the phase and amplitude variations as minimum as possible in the given frequency range. Designed power divider is composed

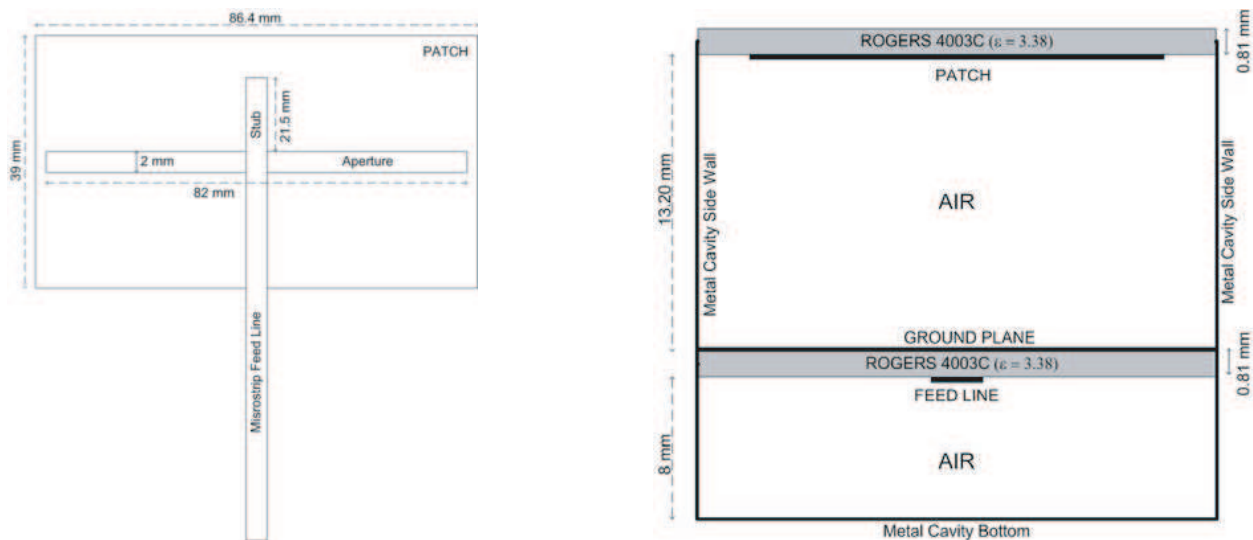


Figure 2: Telemetry antenna bottom view (left), side view (right) with corresponding dimensions.

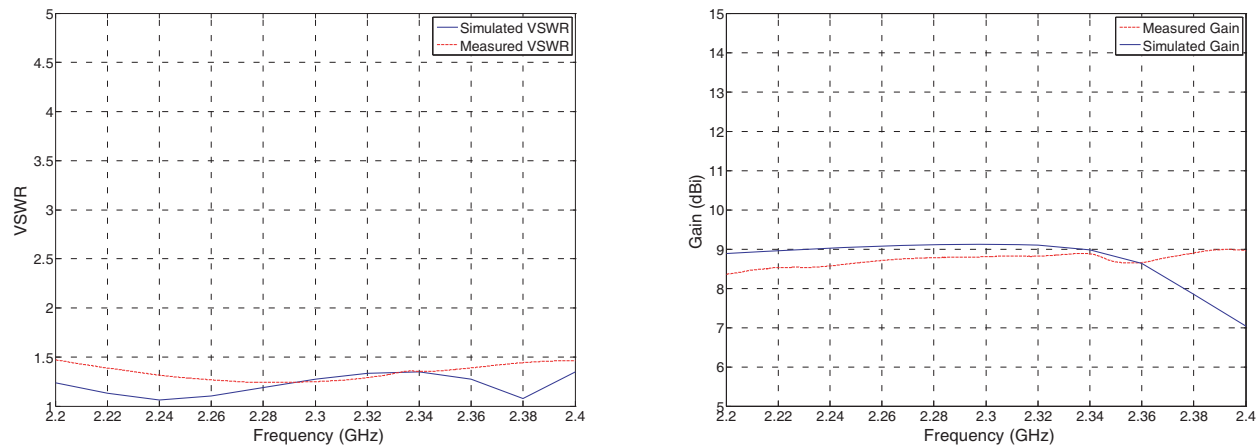


Figure 3: Comparison of simulated/measured VSWR (left) and antenna gain (right).

Table 1: Measured HPBW, CPR and FBR values of manufactured antenna at $f = 2.3$ GHz.

Half-Power Beam Width ($^\circ$)	60°
Cross-Polarization Ratio (dB)	≥ 25 dB
Front-to-Back Ratio (dB)	≥ 25 dB

of three cascaded Wilkinson Dividers [4] as shown in Figure 4. In order to have well isolated output ports we used 100- Ω resistors between the separate arms. Quarter wave section which has 70.7- Ω impedance is in circular geometry in order to have smooth transition from input to the output. Power divider is also printed on the ROGERS 4003C substrate. Simulation results depict that power divider has a VSWR below 1.25 (Figure 5), insertion losses below 6.2 dB (Figure 7). VSWR, insertion loss and port isolation measurements are also performed in the desired frequency range and results are depicted in Figures 5, 6, and 8 respectively.

One important measurement that has to be performed on RF power divider is the phase delay measurements. According to the array configuration of telemetry antennas, all four antennas should be in phase. Thus, there should be no phase difference between the four output terminals of the power divider, unfortunately in practice it is impossible to obtain the same phase but one may keep variations in acceptable range. The measured phase delays which are tabulated in Table 2, predict that phase variation is small enough to tell that all output ports are in phase.

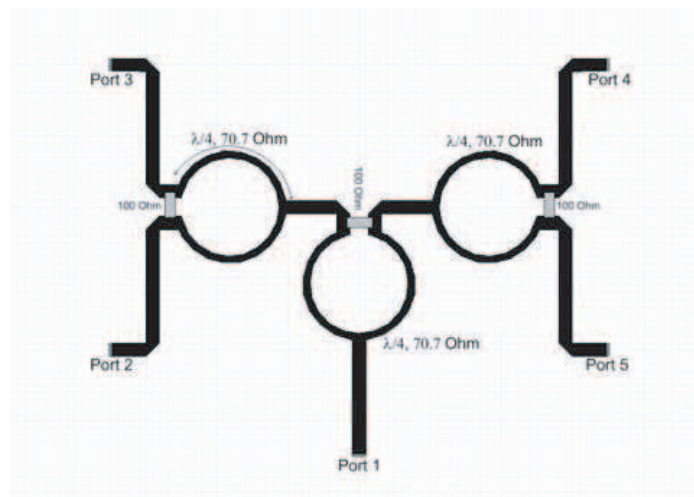


Figure 4: Telemetry system, 1-to-4 RF power divider.

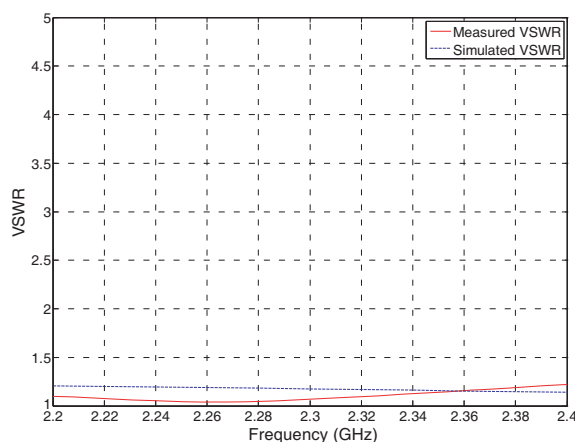


Figure 5: Measured and simulated VSWR of RF power divider.

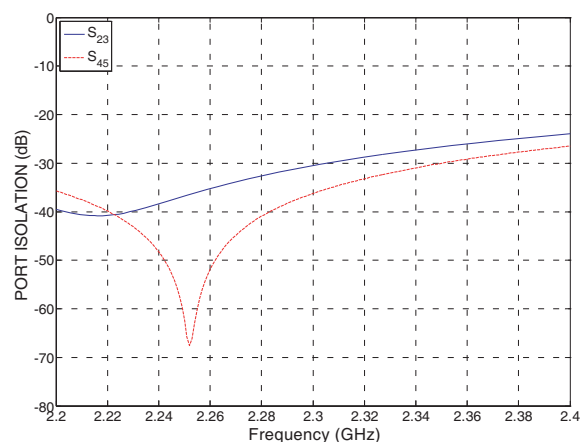


Figure 6: Measured port isolation results of power divider.

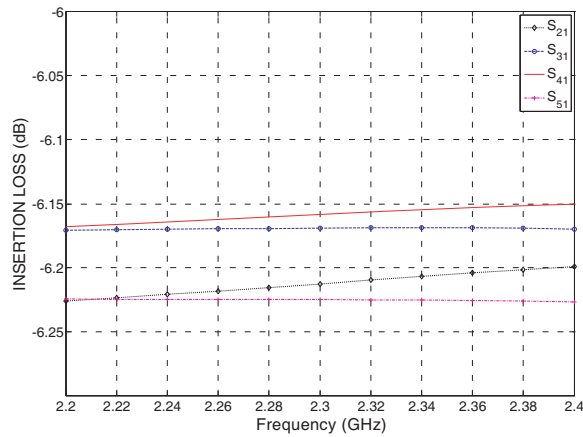


Figure 7: Simulated insertion loss.

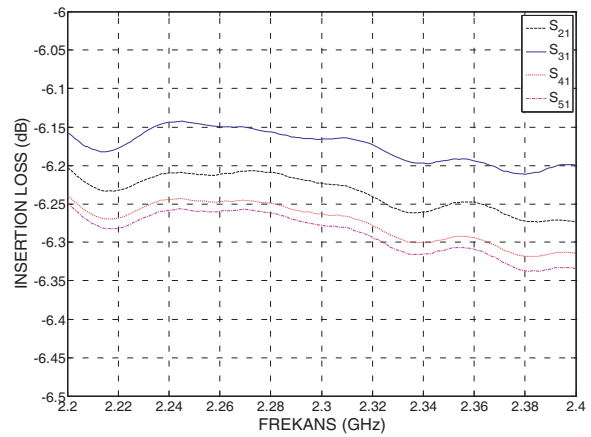


Figure 8: Measured insertion loss.

Table 2: Measured phase delays of RF power divider at different frequencies.

	PHASE (°)		
	2.2 GHz	2.3 GHz	2.4 GHz
S_{21}	-78.005	-98.538	-118.97
S_{31}	-76.372	-96.738	-117.14
S_{41}	-77.625	-98.040	-118.45
S_{51}	-77.556	-98.042	-118.44

4. TELEMETRY ANTENNA SYSTEM

In this context, telemetry system is the combination of RF power divider and the telemetry antennas. Individually, antennas and the power divider work pretty well but the overall system behavior is the most important one. In previous section, we made the insertion loss measurement between port 1 and port 2 by loading the port 3, 4 and 5 with 50 Ohm. In telemetry system all ports see the corresponding telemetry antennas as loads which have VSWR value of 1.5. Therefore the overall system VSWR value will vary as expected which should be below 2 at the end.

We performed VSWR measurements on telemetry system. Measurement setup and the VSWR results are given in Figures 9 and 10 respectively. Measured VSWR values are well below the tolerable value and at the center frequency it is still below 1.5.

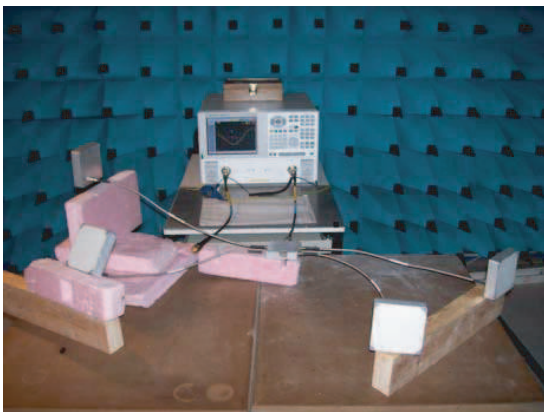


Figure 9: Telemetry system VSWR measurement setup.

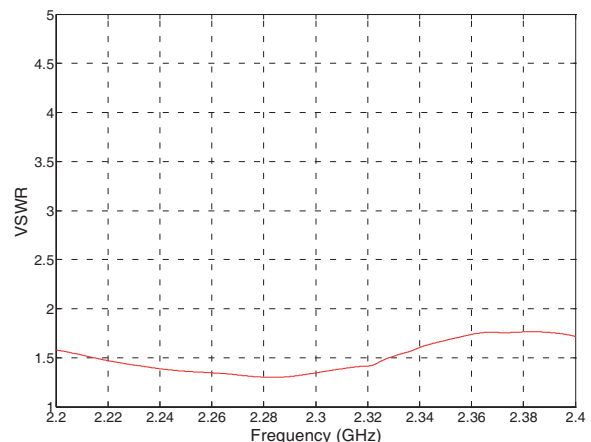


Figure 10: Telemetry system VSWR results.

5. CONCLUSION

In this paper, a proposed telemetry antenna system is investigated in detail with its antennas and RF power divider. Telemetry antennas and RF power divider meet the requirements and demonstrate very good performance individually. Telemetry system performance is also in acceptable range. On the other hand, the system needs some further improvements. Telemetry antennas are very critical here. Telemetry antenna needs very good grounding and it is very sensitive to the stub length, therefore manufacturing process should be very accurate and it should have high repeatability. RF power divider demonstrates very good performance, S_{21} and S_{51} values are 0.1–0.2 dB below from the remaining insertion loss values. There are two regions that the quarter wave circular sections of Wilkinson dividers get closer to each other. One of them is on the path from port-1 to port-2 and one of them is on port-1 to port-5. These regions are the possible cause of the insertion loss difference.

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