Shorted Annular Slot Antenna (ASA) Matched at Three Different Frequencies

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I. Introduction

The multitude of different standards in cell phones and other personal mobile devices require multi-band antennas. The use of the same antenna for a number of different purposes, preferably in different frequencies is highly desirable. The shorted Annular Slot Antenna (ASA) proposed in this paper operates in three different frequencies with the central frequency at 5.8 GHz. It is fabricated on cheap material and is a compact design suitable for integrating in mobile devices. The annular slot antenna on dielectric material has been described explicitly in [1]. The effect of one shorted point along the circumference has been explored in [2] and the effect of capacitive loading is investigated in [3]. A number of papers use different feeding techniques in order to achieve broader bandwidth [4], or to demonstrate multi-band operation, [5] and [6]. In these designs all resonating frequencies are excited simultaneously. In the proposed design only one frequency resonates at a time which is desirable when there are power issues.

II. Antenna Design and Fabrication

The Annular Slot Antenna (ASA) design is presented in fig.1. The shorted slot is printed on the front side, and the feeding line with the matching stubs, are printed on the back side of the board, using standard photolithography. The antenna is fabricated on a 635 μm thick, low loss (tanδ=0.0025) Rogers RO3006 with ε_r=6.15 and a copper thickness of 18 μm. The antenna is fed by a 50 Ω microstrip line with width of 0.92 mm and the matching stubs are also 0.92 mm wide. The slot has an outer radius R=10 mm and inner radius 8 mm resulting a slot width of 2 mm. The feeding line is 25 mm long and the end of the line is at the slot center. Consequently D1=15 mm. The stub (1) with L2=4.21 at D3=7.27 mm matches the radiating element at the center frequency of 5.8 GHz. The simulated radiation efficiency was 92% at this frequency. With the use of an additional matching stub (2) a different frequency can be matched. When the second stub has length L1=4.98 mm and D2=5.49 mm, combined with stub (1), the antenna resonates at 5.2 GHz. If alternatively L1=3.22 mm and D2=4.1 mm, combined with stub (1), the slot antenna resonates at 6.4 GHz. Since the radiating element radiates with high efficiency in a wide band [4] the problem is the matching in order to avoid reflections before the guided signal actually gets to the slot. Since each matching network is optimized at a certain frequency the whole structure radiates with high efficiency. Simulations showed radiation efficiency higher than 82% in all three different frequencies. The outer part of the slot is used as the ground plane for the microstrip line on the back side. The ground plane occupies most of the required space. The whole board used is 50 mm x 50 mm. (S=50 mm) while the slot and the feeding line with the stubs can be confined in a rectangle area 20 mm x 35mm big.

III. Discussion of Measurements and Simulated Results

For the return loss and radiation pattern measurements a 3.5 mm SMA connector was soldered on the microstip line, and an HP 8530A network analyzer was used. The return loss simulations and measurements are presented in fig. 2. For the 5.8 GHz frequency, measurement matches the simulation in great detail, both in frequency position and in the resonance depth. Return loss lower than -20 db is measured which implies 99% radiation. For the lower frequency at 5.2 GHz there is a small shift of the resonance towards lower frequencies. The simulated resonance frequency was 5.2 GHz and the measured was 5.1 GHz. A similar small shift is noticed for the higher frequency as well. The simulated resonance frequency was 6.4 GHz and the measured resonance was 6.2 GHz. Those small shifts are caused from fabrication and measurement inaccuracies. Especially the discontinuity caused from the soldered connector can cause significant shifts in return loss measurements.

The radiation patterns presented in figs. 3-5 lay on a plane perpendicular to the directivity direction which is parallel to z axis and also perpendicular to both E and H planes. E_φ component is measured and simulated. The E_θ component on that plane (cross polarization) is much smaller (more than 20 dB). The x axis corresponds to $\varphi=0^o$ and y axis corresponds to $\varphi=90^o$. The axes orientation with respect to the antenna orientation, appear in fig. 1. Fig. 3 shows the simulated radiation pattern when no short is placed along the circumference of the slot. A null is observed in the feeding line direction. When a short is placed along the circumference, it causes a shift in the radiation pattern as seen in fig.4. Specifically, for the central frequency, the null appears at 180 degree from the location of the short. For the other two frequencies there is a shift in the null position from 180 degree. For the 6.4 GHz frequency, the wavelength is smaller compared to the wavelength for the central frequency and that causes the null to shift towards the short. For the 5.2 GHz frequency, the null direction shifts farther from the short because the wavelength is larger compared to the 5.8 GHz wavelength. Thus, although there is a similar E field distribution along the circumference for all three frequencies, with a minimum at the short, the different wavelength of those frequencies results in a shift in the null position observed in fig. 4. The E_φ field is measured for the 5.8 GHz frequency. The simulation and measurement results at 5.8 GHz are presented on the same diagram for comparison in fig. 5. Good agreement is observed. The measurement verifies the simulation in both the direction and the depth of the null. The smaller dip on the pattern, observed close to 115^o, is within measurement tolerances.

IV. Conclusion

A compact shorted annular slot antenna was presented. The proposed antenna design can be easily fabricated on a low-cost Duroid material and can be easily packaged and integrated with other components. The compact size and the operation frequency make it suitable for personal mobile devices. The simulations agree fairly well with the measurements. All the matching stubs can be printed on the same board and with the selective use of them, a frequency reconfigurable antenna can be designed. The placement of a short along the slot circumference rotates the radiation pattern on the x-y plane. With the appropriate placement of shorts a reconfigurable radiation pattern can also be achieved.

References:

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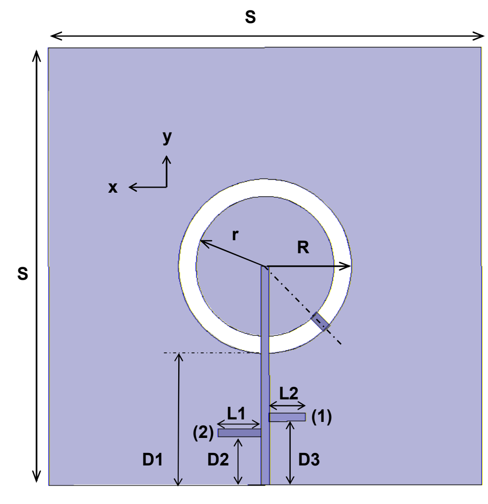

Fig. 1. ASA design. The feeding line and the stubs are in the back side of the board.

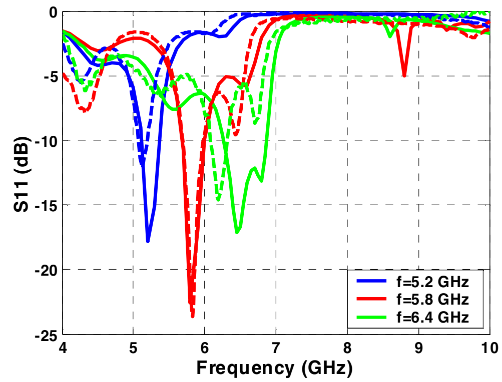

Fig. 2. Return loss. Simulation is in solid line while measurement is in dashed line.

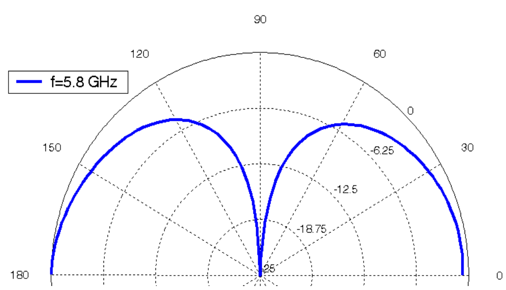

Fig. 3. E_φ radiation pattern at 5.8 GHz for slot without short.

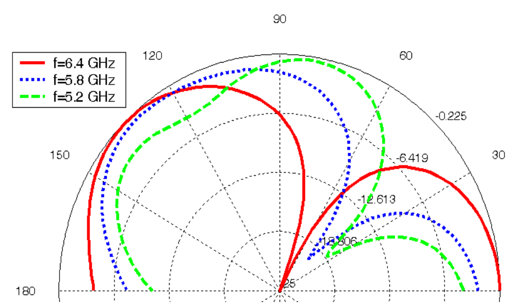

Fig. 4. E_φ radiation pattern at three different frequencies.

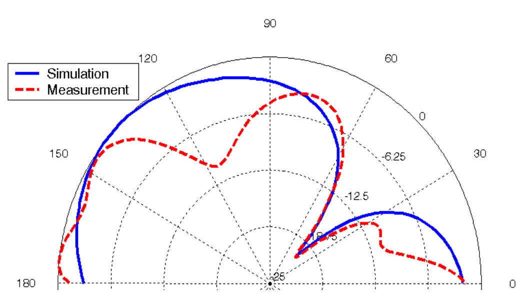

Fig. 5. E_φ radiation pattern at 5.8 GHz, with the short along the slot circumference.