

TANGENTIALLY FED BROADBAND ANNULAR SLOT ANTENNA FOR WLAN APPLICATIONS

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ABSTRACT

A tangentially fed wide frequency bandwidth Annular Slot Antenna (ASA) is reported. Two prototypes operating in the wireless local area network (WLAN) 5 GHz band have been designed and measured. The first antenna uses a single ASA and presents 11% bandwidth of $VSWR < 2$. By using two ASA on either side of a microstrip feeding line, the frequency bandwidth of $VSWR < 2$ reaches 20% and a significant improvement of the antenna cross-polarization is obtained. The radiation patterns are similar to those obtained with a conventional ASA feed [1]. Experimental results agree with theoretical predictions.

INTRODUCTION

Future high speed Wireless Local Area Networks (WLAN) will operate in the 5GHz band and will offer data rates up to 54 Mbit/s. As shown in Table 1, the US Institute of Electrical and Electronics Engineers (IEEE), the European Telecommunications Standards Institute (ETSI) and the Japanese Association of Radio Industries and Business (ARIB) are developing their respective standards and several separate frequency bands have already been reserved at 5 GHz for this application [2,3,4].

For domestic applications, antennas should be low-cost and small size, should introduce minimum loss and present a quasi-omni directional coverage. The ASA has been identified as a potential solution for these applications [5]. Conventional feeding of the ASA by electromagnetic coupling to a microstrip feeding line using a low cost substrate, commonly used for consumer applications, gives a bandwidth of 5 to 10%. For example, the achieved bandwidth at 5.8GHz using the ROGERS substrate RO4003 ($\epsilon_r=3.38$, $\tan\delta=0.0027$, $h=0.81\text{mm}$) is 7.5 %. That is insufficient to cover the full 5GHz bandwidth.

A new feeding technique of the ASA with circular polarization allowing a VSWR frequency bandwidth of approximately 19% has been proposed [6]. In this paper a different feeding solution allowing the coverage of the full 5 GHz WLAN bands is proposed [7]. This solution provides linear polarization with fairly good cross polarization over 20% bandwidth.

SINGLE TANGENTIALLY FED ASA

A/ Structure description

The antenna structure is shown in Figure 1. As sketched in Figure 2, the ASA is magnetically coupled to a feeding microstrip line etched on the opposite side of the supporting substrate.

Indeed, in order to maximize the coupling to the ASA, the open-ended microstrip line should extend by a length of about $\lambda_m/4$ from the closest point to the ASA, where λ_m is the guided wavelength under the microstrip line at the resonant frequency of the ASA. Thus, the magnetic field of the microstrip line is maximal in the coupling area. The obtained polarization is linear and parallel to the feeding microstrip line. The perimeter of the annular slot is around λ_s with λ_s the guided wavelength in the slot at the resonant frequency. The width of the microstrip line and the 'y' distance between the microstrip axis and the slot axis are adjusted for coupling optimization.

B/ Optimization of the microstrip line ASA coupling

The 'y' parameter controls both the impedance matching and the cross-polarization of the ASA. The annular slot antenna described has been designed on ROGERS substrate RO4003 ($\epsilon_r=3.38$, $\tan\delta=0.0027$, $h=0.81\text{mm}$), at a central frequency of 5.7 GHz using the IE3D software from

ZELAND. The 'y' values vary from -0.6mm to 0.6mm, and for each 'y' value the impedance matching of the ASA has been optimized in order to obtain the widest frequency bandwidth.

As shown in Figure 3, it has been found that the farther the microstrip line is from the slot, the narrower is the frequency bandwidth.

However, the level of the cross-polarization discrimination (XPD) increases when the microstrip feeding line is closer to the ASA. Obtained results for the simulated 'y' values are summarized in Table 2. The simulated efficiency is higher than 87% for all 'y' values.

C/ Measurement results

The antenna with 'y' value of +0.3mm, presenting an acceptable trade-off between the frequency bandwidth and the cross-polarization level, has been realized (Figure 4). Figure 5 shows simulated and measured impedance matching of the ASA. The obtained bandwidth (11.1% for $|S_{11}| < -10\text{dB}$) is predicted well by the simulation.

Radiation patterns of the single ASA antenna have been measured in both E and H planes and are shown in Figure 6. While the co-polarized radiation patterns and antenna efficiency are very similar to the ASA fed with a conventional feed, the measured cross-polarization (-9.4dB) is surprisingly higher than expected from simulations (-21dB).

The finite size of the substrate explains in part the discrepancy between the measured and simulated cross-polarization levels. A second simulation using HFSS software and taking into account the finite size of the substrate gives a cross-polarization level of -17dB rather than -21dB obtained with IE3D. The remaining difference between simulation and measurement could be due to realization tolerances in particular on the distance 'y' between the ASA and the feeding line.

DOUBLE TANGENTIALLY FED ASA

A/ Structure description

The wide band frequency behavior of the tangential feeding structure could be due to the extension of the coupling region around the short circuit plane of the microstrip line. However, this extended coupling area generates cross-polarization components of the electrical field. In order to improve the cross-polarization of the antenna, a new structure using two ASA on either side of the microstrip feeding line is proposed (Figure 7). As sketched in Figure 8, the cross-polarization generated by each ASA will cancel each other out. The obtained polarization is linear, parallel to the feeding line, with a higher purity of polarization than that obtained with a single ASA.

In order to preserve the central frequency of the antenna, the perimeter of each annular slot is chosen slightly lower than λ_s with λ_s the guided wavelength in the slot.

B/ Measurement results

A double tangentially fed ASA structure has been designed using the IE3D software. It has been realized on the same ROGERS substrate (Figure 9) and experimentally evaluated.

Figure 10 shows the measured radiation patterns of the new realized antenna in the E and H planes at the central frequency of 5.7 GHz. The measured cross-polarization is lower than -19.1 dB (rather than -9.4 dB obtained with a single ASA), confirming the cross-polarization improvements brought by the association of the 2 ASA.

Figure 11 shows the measured return loss of the antenna compared with simulation. Good agreement between measurement and simulation can be noticed. A total matching bandwidth of 20% has been measured. This increase in the frequency bandwidth of the double ASA in comparison with a single ASA could be explained by the coupling of the two closely spaced slot resonators.

CONCLUSION

Two tangentially fed annular slot antennas (ASA) have been designed and measured. The single tangentially fed ASA presents a VSWR bandwidth of 11% and has a maximum cross-polarization of -9.4dB. By placing two ASA on either side of the feeding microstrip feeding line the cross-polarization is reduced to a value of -19.1 dB while 20% frequency bandwidth for $\text{VSWR} < 2$ is measured for the antenna. Taking into account, realization and substrate tolerances, the designed double ASA should allow the coverage of the full WLAN 5 GHz bands.

REFERENCES

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	IEEE [2]	ETSI [3]	ARIB [4]
Frequency allocation (GHz)	5.15-5.35 5.725-5.825	5.15-5.35 5.47-5.725	5.15-5.25
Relative bandwidth	12.3%	10.6%	3.8%

Table 1 : Frequency allocations of 3 main WLAN standards

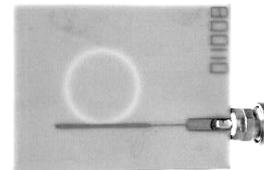


Figure 3 : Single tangentially fed ASA (Realization)

Y value (mm)	-0.6	-0.3	0	0.3	0.6
Bandwidth @ -10dB (%)	17.2	14.8	12.8	11	7.9
Max of XPD level @5.7GHz (dB)	-5.8	-8.8	-14	-21	-30
Efficiency @5.7GHz (%)	87.1	89.4	90.2	89.1	89.9

Table 2 : Bandwidth, XPD level and efficiency of ASA for several ‘y’ values (Simulation)

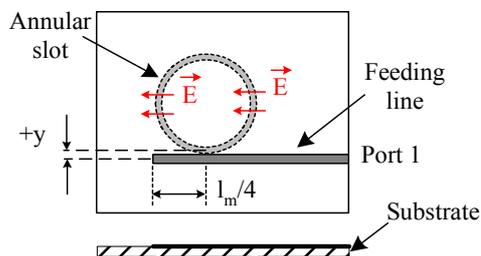


Figure 1 : Single tangentially fed ASA

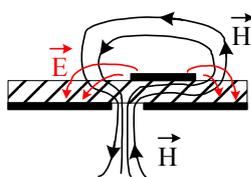


Figure 2 : Coupling between microstrip line and annular slot

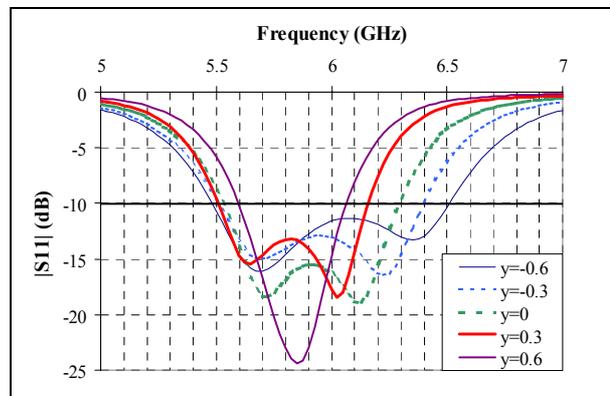


Figure 4 : Impedance matching of tangentially fed ASA for several ‘y’ value (Simulation)

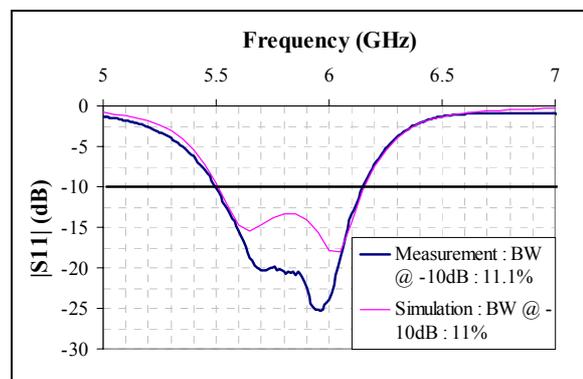


Figure 5 : Impedance matching of single tangentially fed ASA

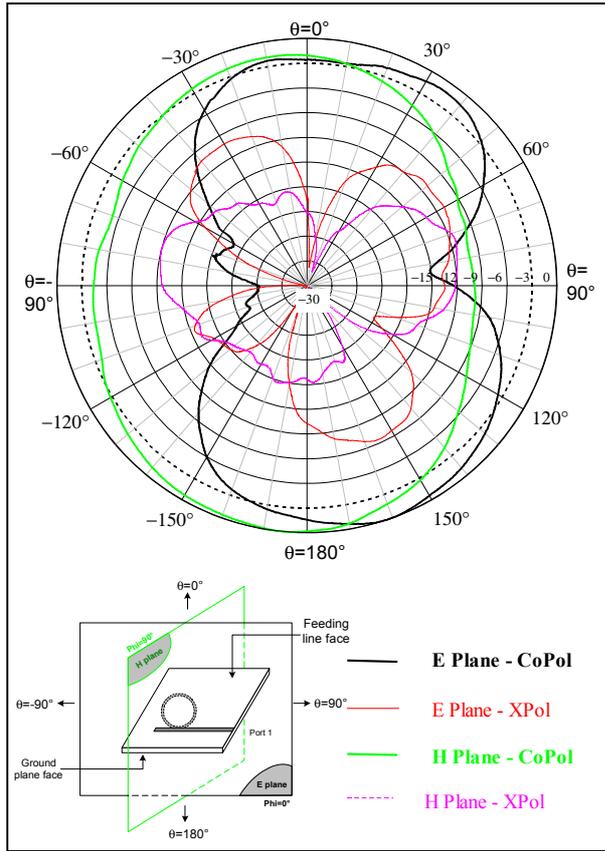


Figure 6 : Radiation pattern of the ASA @5.7GHz (Measurement)

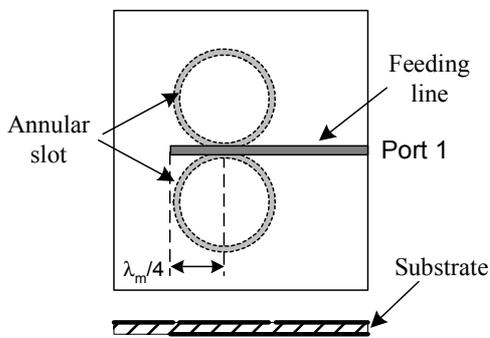


Figure 7 : Double tangentially fed ASA

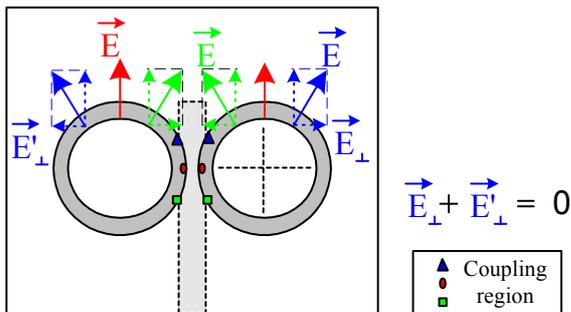


Figure 8 : Double ASA showing the cancellation of XP component

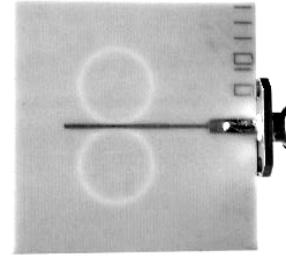


Figure 9 : Double tangentially fed ASA (Realization)

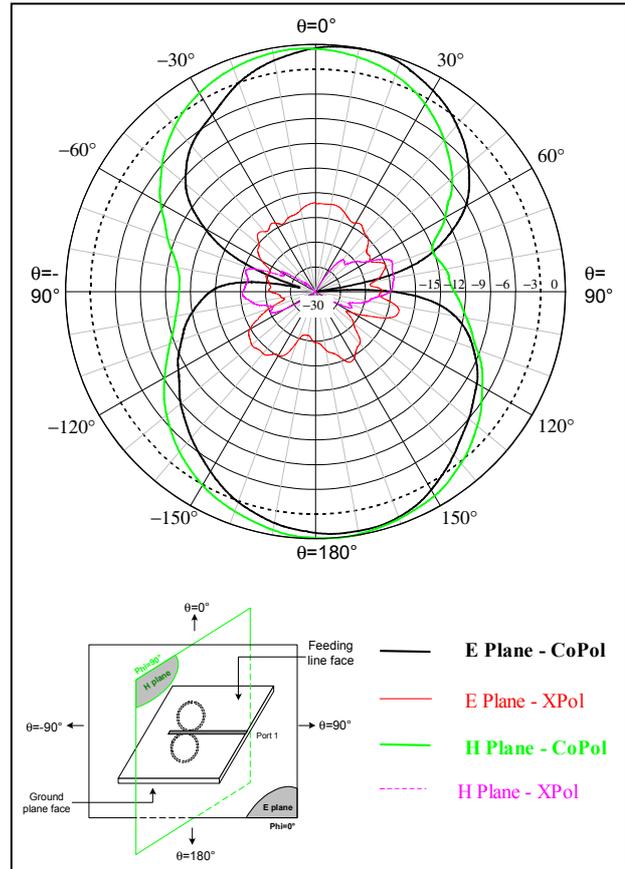


Figure 10 : Radiation pattern of the double ASA @5.7GHz (Measurement)

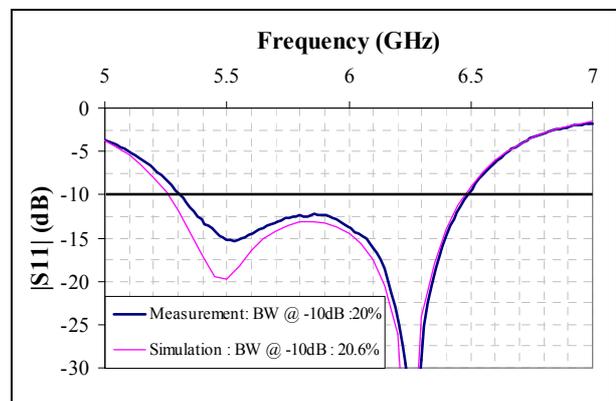


Figure 11 : Impedance matching of double tangentially fed ASA