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Switched Beam 3D-Vivaldi Antennas for WLAN Applications.

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1. Introduction

Wireless Local Area Network (WLAN) is now widely deployed in companies, public areas and home environments. This success is due to the very low cost of the equipments, the ease of installation and the low maintenance cost. However, with the multiplication of the number of access points and users, the capacity of wireless networks is becoming interference-limited rather than noise limited. The use of multi-sector antennas, comprising several narrow beams, can help to solve the interference issue while improving the wireless range or/and bit rate [1-5].Various multi-sectored antennas have been designed and produced in the recent past years based on an omnidirectional antenna by altering the environment [1-3] or the antenna feeding [4]. Another widespread technique consists in using a dedicated antenna for each sector [5-7], dividing the space into multiple sectors. Most of these solutions use a planar design while a volume antenna features significant advantages thanks to their ability to offer higher design flexibility and radiation pattern control (E and H planes).

Following these considerations, a conceptually simple 3D multi-sector antenna based on an innovative layout of vertical Vivaldi-type antennas combined with an horizontal motherboard is introduced in this paper. This layout offers a great flexibility in parameters such as shape, position and dimensions of the Vivaldi antenna. Compared to planar antenna design, here the number of sectors as well as the gain of each beam can be chosen among a large set of values in order to fit to the shape and dimensions of the existing horizontal motherboard of the system.

First a 4-sector 4.8-6GHz antenna based on a common FR4 laminate and mounted onto a FR4 switching board has been designed as a proof of concept. Then, in order to target consumer market and to reduce the manufacturing costs in high volume production, the metallized molded plastic technology which enables molding 3D complex structures is preferred to design this antenna. A second multi-sector antenna made of Pocan Poly-Butylene Terephthalate (PBT) plastic material has been designed by considering metallized plastic technology constraints.

2. Concept of the multi-sector antenna and structure description

The Vivaldi reference antenna presented in Figure 1 is fed through a microstrip to slotline transition. The dimensions of the Vivaldi antennas with circular profile are chosen as following: 33mm (0.66λ) for the length of the profile, 33mm (0.66λ) for the width of the aperture and a 0.67mm thick FR4 substrate (0.013λ). The gain associated is close to 5.8dBi with a half-power beamwidth of 120° in the H-plane at 6GHz.

The new concept of the Vivaldi-based multi-sector antenna is illustrated in Figure 2. The Vivaldi reference antenna is combined with an horizontal PCB which enlarges the -10dB useful frequency band. Rather than using several Vivaldi antennas arranged on a uni-planar microstrip substrate to cover the entire 360° of the azimuth plane [6], the multi-sector device is composed of several antennas vertically placed around a common central axis and mounted onto the existing motherboard of the system (Figure 3). Thanks to the use of the third dimension this arrangement offers much more freedom in the optimization of the radiation pattern (E and H planes), as well as the control of the gain within each beam and the number of sectors [7].

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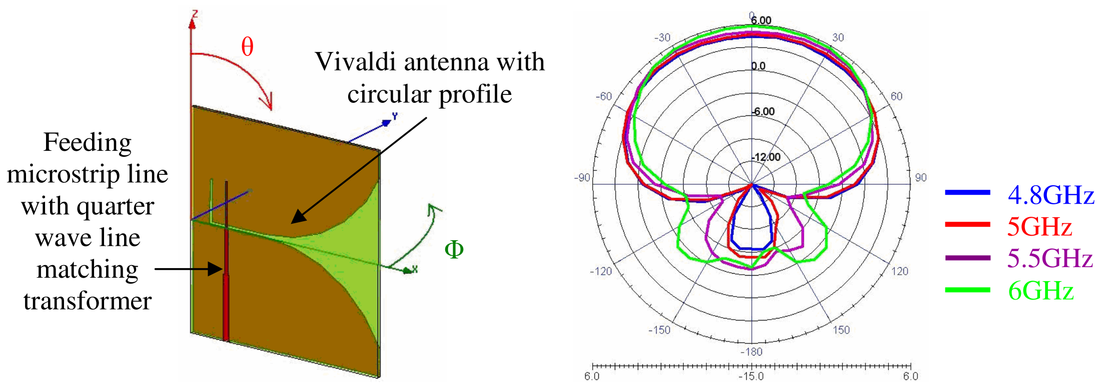


Figure 1: Vivaldi reference antenna and associated radiation pattern in the H-plane (θ=90°)

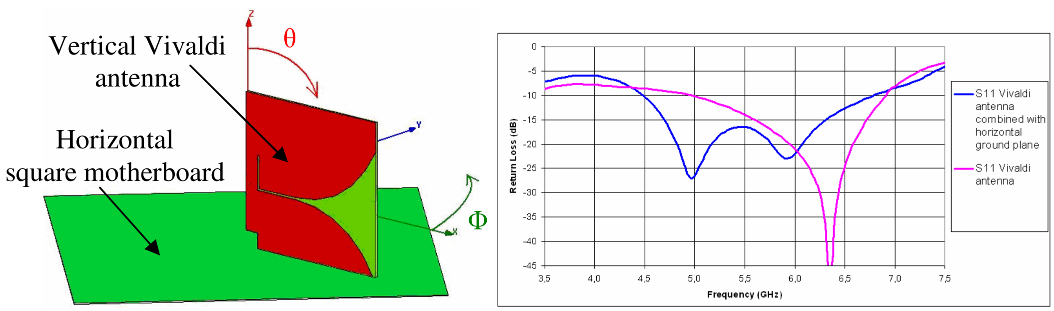


Figure 2: Vivaldi antenna combined with horizontal motherboard and associated return loss

3. Four-sector antenna system design: simulations and results

To prove the concept a first 4-sector antenna, based on the commonly used FR4 laminate and mounted onto also a FR4 board, has been designed in the 4.8-6GHz band for WLAN applications. Each individual antenna is located at 90° from each other in a vertical arrangement and the beams are switched using a single-pole 4-throw switch (SP4T) set at the bottom of the 90*90mm² (1.8λ) motherboard with the feeding circuits. To allow an experimental validation and to create a device suitable for mass-production at low cost, we have developed a 3D 4-sector plastic antenna working in the same useful band.

3.1 First solution using basic FR4 laminate

The 4-sector antenna structure is presented in Figure 3 with the simulated performances when one sector is active. A 43% relative bandwidth, centred at 5.4 GHz, is obtained for –10 dB return loss. As the isolation levels are higher than 22dB in the 4.8-6GHz band, the mute antennas cannot disturb the active antenna. Maximal gain simulated is the same as for the reference antenna i.e. 5.8dBi at 6GHz. The azimuth half-power beamwidth of 120° allows to cover the entire azimuth direction with a -3dB beamwidth of 55° in elevation plane (Figure 4).

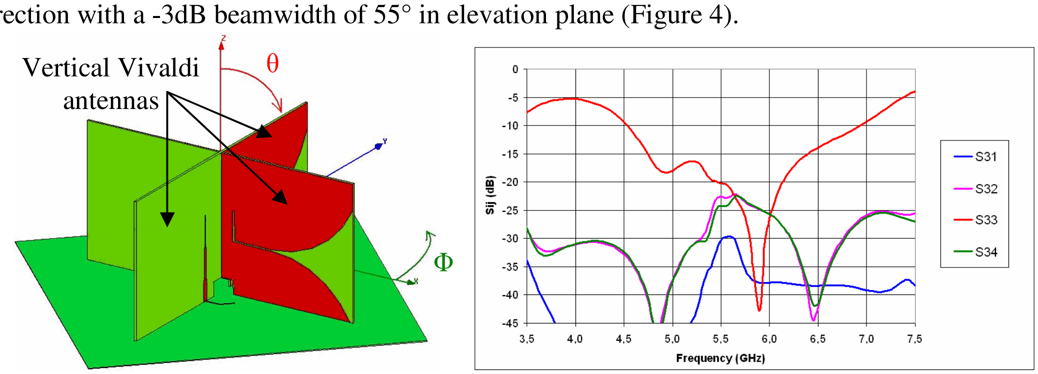


Figure 3 : 4-sector switched beam antenna in FR4 substrate and associated simulated Sij

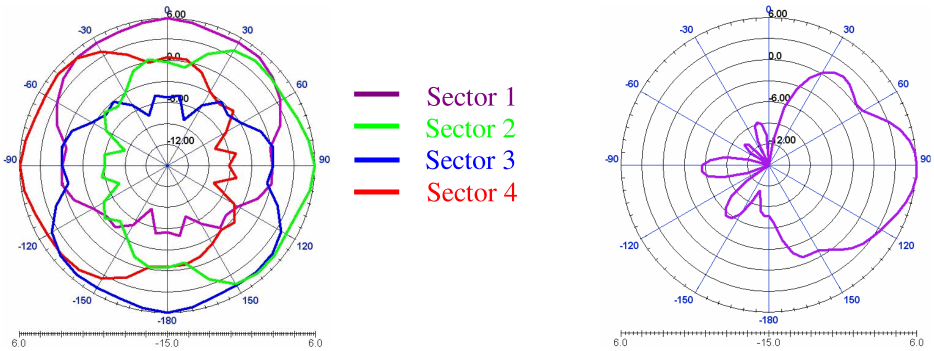
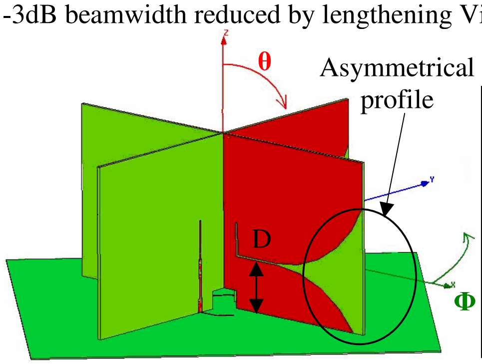


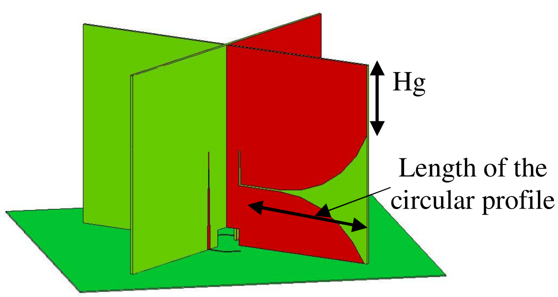
Figure 4 : Radiation pattern at 6GHz in the azimuth plane (θ=90°) and in the elevation plane (Φ=0°)

The flexibility of the antenna shape permits a modification of the radiation pattern characteristics. The mean beam could be tilted upwards with an asymmetrical antenna profile and/or the growth of the motherboard physical size (Figure 5). Likewise, antenna gain can be increased and -3dB beamwidth reduced by lengthening Vivaldi Antenna profile or height "Hg" in Figure 6.



Parameters	Simulated values at 6GHz		
Motherboard dimensions (mm^2)	90*90 (1.8λ*1.8λ)	90*90 (1.8λ*1.8λ)	120*120 (2.4λ*2.4λ)
D (mm)	17 (symmetrical profile)	12 (asymmetrical profile)	
Elevation tilt (°)	0	20	30

Figure 5: 3D 4-sector antenna with asymmetrical profile and larger motherboard



Parameters	Simulated values at 6GHz		
Length (mm)	34mm (0.68λ)	34mm (0.68λ)	39mm (0.78λ)
Hg (mm)	7 (0.14λ)	17 (0.34λ)	7 (0.14λ)
Gain (dBi)	5.8	7	6.7
HPBW (°)	120	80	60

Figure 6: 4-sector antenna with different profiles

3.2 Plastic solution in Pocan (PBT) material

Vivaldi antennas of the second prototype are manufactured with Pocan PBT based plastic material (ε_r=3.4, tan δ=0.01 @6GHz). The MID (Molded Interconnect Device) antenna prototype is first molded with plastic material and then metallized in chemical baths after laser activation. As shown in Figure 7, multi-sector antenna plastic part is directly mounted on a horizontal motherboard including the feeding and switching circuits. The transitions between vertical and horizontal (on the motherboard) microstrip lines are obtained by a mechanical contact between metallized plastic pins and plated through holes inside the PCB.

Figure 8 shows the simulated performances of this 4-sector antenna combined with the FR4 motherboard. The plastic antenna is wide-band, return loss is below -10dB from 4.6GHz to 7.3GHz. In the useful band, the isolation levels for consecutive antennas are below -23 dB and -30 dB for diametrically opposite antennas. Loss tangent of Pocan plastic material being smaller than FR4 one allows a maximal gain of 6.4dBi. The corresponding azimuth half-power beamwidth of 110° covers the entire azimuth direction with a crossover depth of -1.9dB.

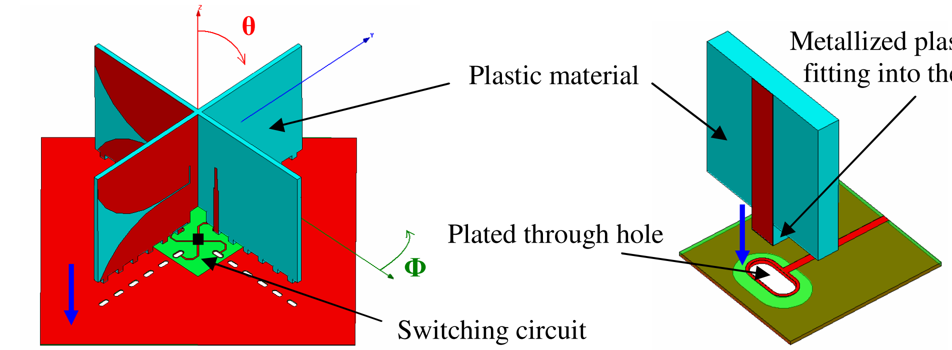


Figure 7: Plastic antenna system assembly on the horizontal motherboard

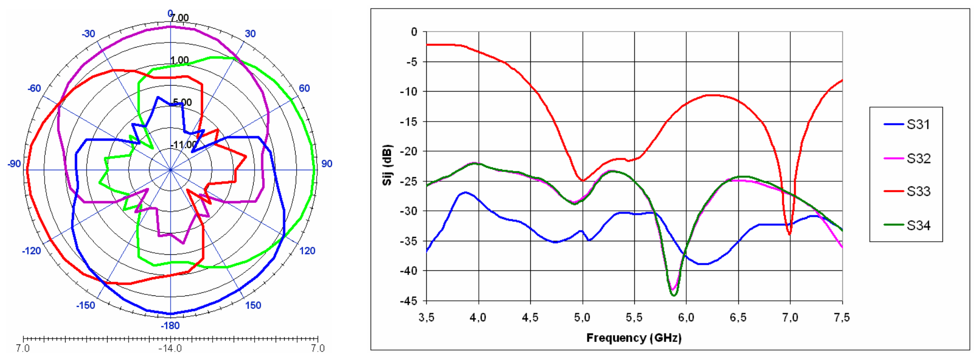


Figure 8 : Radiation pattern at 6GHz in the azimuth plane and S-parameters

4. Conclusion

A novel design and simulation results of a wide-band 3D multi-sector antenna composed of several Vivaldi-type antennas have been introduced and validated by the design of two 4-sector antennas made of common FR4 substrate and Pocan plastic material in the 4.8-6GHz band. The multi-sector antenna is associated with an integrated 1 to 4-port switch placed on the horizontal motherboard with the other electronics parts of the system like feeding circuits. This novelty offers a great flexibility of radiation patterns and performances (number of sectors, shape, positioning and dimensions). Furthermore, the 3D plastic device fits suitably in an existing substrate of a system by means of metallized pins and holes. The realization of the two proposed antenna prototypes is in progress and experimental results will be presented during the conference.

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