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3D Multi-Sector Vivaldi Antennas Based on Metallized Plastic Technology

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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 past recent years based on an omnidirectional antenna by altering the environment [1-3] or the power supply [4]. Another widespread technique consists in using a dedicated antenna for each sector [5-7], space division into multiple sectors. Most of these solutions use a planar design while a significant advantage of volume antennas is 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 original layout of Vivaldi-type antennas and compatible with metallised plastic manufacturing technology is introduced in this paper. The solution offers a great freedom in shapes and dimensions for the Vivaldi antenna and a large choice in the number of sectors and gain of each beam. The use of metallized plastic technology, based on molding 3D complex structures enables mass production of the antenna at low cost. To prove the concept a 4-sector antenna, based on a Vestodur Poly-Butylene Terephthalate (PBT) plastic material and mounted onto a FR4 switching board, has been designed in the 4.8-6 GHz band.

Concept of the multi-sector antenna and structure description

The novel concept of the Vivaldi-based multi-sector antenna is illustrated in Figure 1. Rather than using several Vivaldi antennas arranged on a uni-planar microstrip substrate to cover the entire 360° of the azimuth plane [7], the antennas are in this case vertically placed around a common central axis. 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. In order to target consumer market and to reduce the manufacturing costs the metallized molded plastic technology is preferred to design this antenna.

As shown in Figure 2, the constructed device is directly mounted on a horizontal microstrip motherboard including the feeding and switching circuits. Each Vivaldi antenna is fed through a microstrip to slotline transition performed on the vertical plane. 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. The motherboard which can contain other parts of the circuits

constitutes an integral part of the antenna system and should necessarily be taken into account during the antenna design. The motherboard features (shape, dimensions, etc.) offer additional optimization parameters of the radiation pattern and the multi-sector antenna matching.

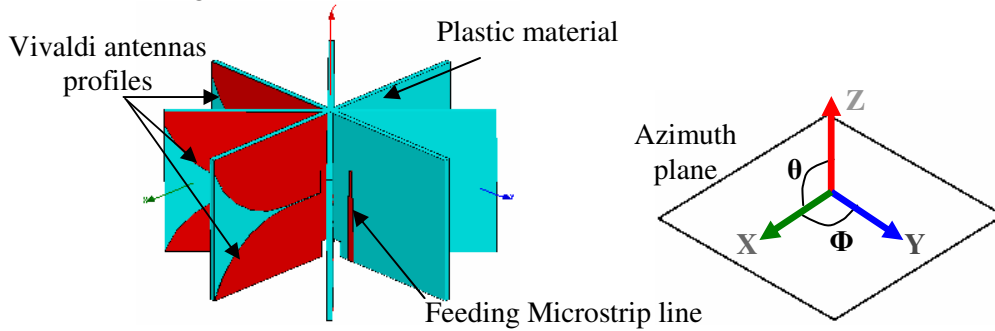


Fig. 1: 8 Vivaldi antennas placed vertically around a common central axis.

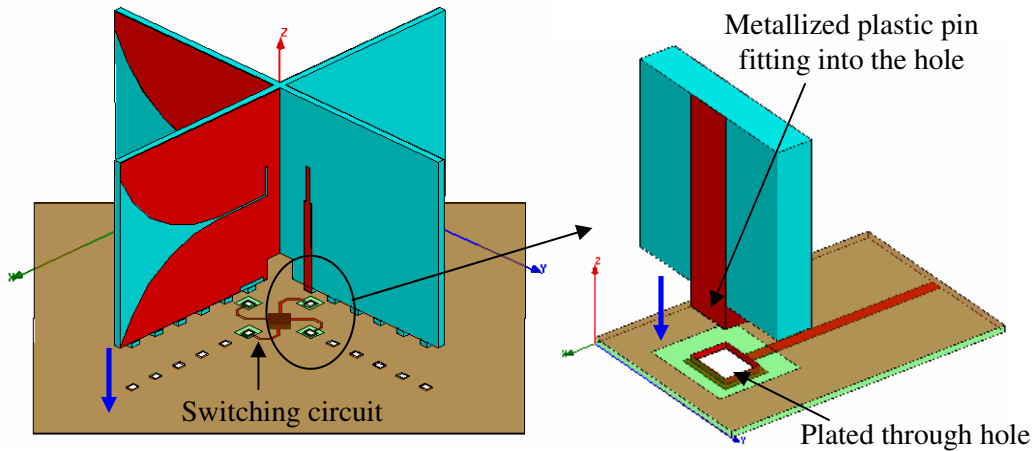


Fig. 2: Plastic antenna system assembly on the horizontal motherboard.

4-sector antenna system design: simulations and results

To allow an experimental validation and to create a device suitable for mass-production at low cost, we have developed a 3D 4-sector antenna working in the [4.8-6] GHz band. The MID (Molded Interconnect Device) antenna prototype is first molded with plastic material and then metallized in chemical baths after laser activation. The plastic used is the Vestodur 2230 ($\epsilon_r=3.7$, $\tan \delta=0.0012$) PBT based.

The simulations of the prototype presented in Figure 2 were carried out using the Finite-Element-Method (FEM) Ansoft's HFSS[®] software. In order to insure 90° beamwidth for a single sector in the azimuth plane, the dimensions of the Vivaldi antennas with circular profile are chosen as: 34 mm for the length of the profile, 35 mm for the aperture, 27.5 mm for the radius and a 1.5 mm ($\lambda/40$) thickness imposed by the manufacturing constraints. The beams of the multi-sector antenna are switched using a single-pole 4-throw switch (the Hexawave HWS451 SP4T) set at the bottom of the 90*90 mm² motherboard with the feeding circuits.

Figures 3 and 4 show the simulated performances of this 4-sector antenna combined with the motherboard. A 50% relative bandwidth, centred at 5.4 GHz, is obtained for -10 dB return loss. Figure 4 shows a close match between each response of the 4 sectors. In the useful band, the isolation levels for consecutive antennas are under -23 dB and lower than -31 dB for symmetrically opposed antennas.

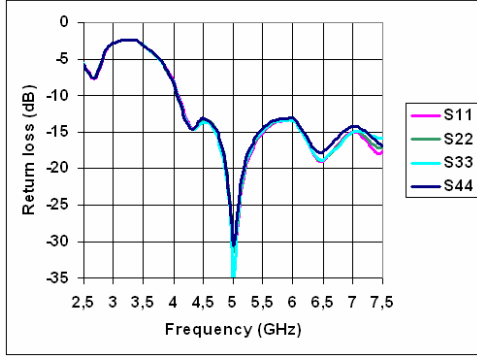


Fig. 3: Simulated S11 of the 4-sector switched beam antenna.

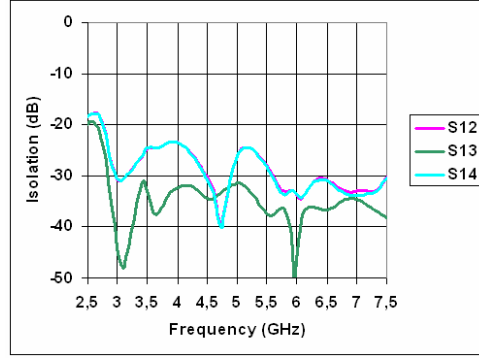


Fig. 4: Isolation between different ways when one sector is active.

As regards the radiation pattern, each sector is individually triggered and generates the same radiation pattern with an angular shift of 90° (Fig. 5). The maximal gain obtained is near 6 dBi, the directivity at 7.3 dBi, and the front-to-back ratio at around 12 dB with corresponding azimuth half-power beamwidth of 95° (Fig. 6). With these performances the multi-sector antenna covers the entire azimuth direction with a crossover depth of -3 dB.

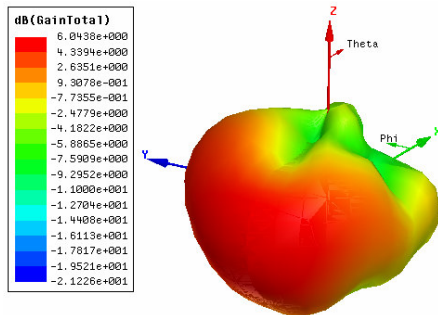


Fig. 5: Radiation pattern at 6 GHz when one sector is active.

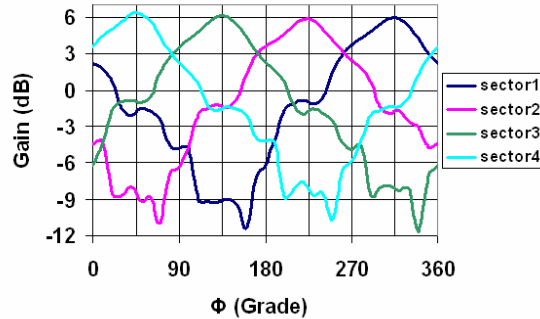


Fig. 6: Radiation pattern in the azimuth plane at 6 GHz.

The flexibility of the antenna form permits a modification of the radiation pattern characteristic. The mean beam could be tilted upwards with a asymmetrical antenna profile and/or the growth of the motherboard physical size (Fig. 7). Likewise, Gain of the antenna can be increased and half power beamwidth reduced by lengthening the Vivaldi Antenna profile (Fig. 8).

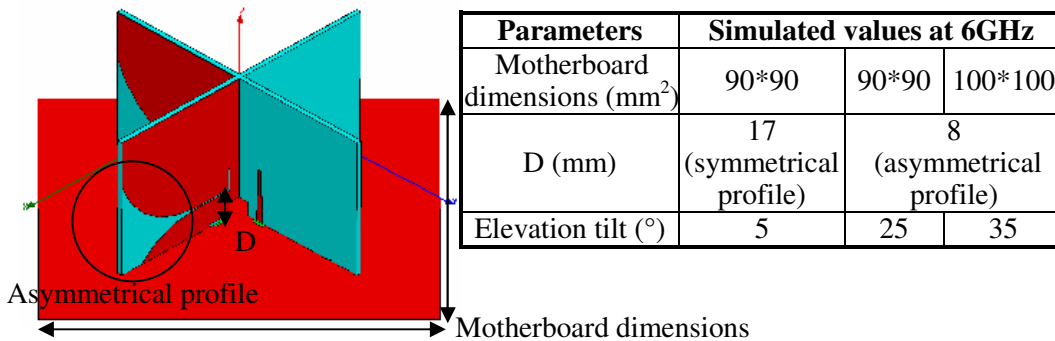


Fig. 7: 3D 4-sector antenna with asymmetrical profile and larger motherboard.

Parameters	Simulated values at 6GHz		
Length (mm)	30.5	34	41.5
Gain (dBi)	4.9	6	6.6
HPBW (°)	115	95	75

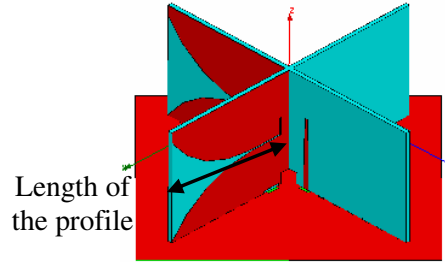


Fig. 8: 3D 4-sector antenna with profiles of different lengths.

Conclusion

A novel design and simulation results of a wide-band 3D multi-sector antenna composed of Vivaldi-type antennas have been introduced. The proof-of-concept is validated by the design of a four-sector antenna in the [4.8-6] GHz band. Each individual antenna is located at 90° from each other in a vertical arrangement and mounted on a motherboard in an appropriate manner. The multi-sector antenna is associated with an integrated 1 to 4-port switch placed on the horizontal motherboard. The antenna structure itself is based on a plastic material that enables low-cost and mass production capabilities of molded and metallized 3D designs, whereas the motherboard is made of common FR4 substrate. This novelty offers a great flexibility of radiation patterns and performances (number of sectors, shape and dimensions). Furthermore, the 3D plastic device allows an easier integration onto an existing substrate of a system by means of metallized pins and holes. The realization of the proposed antenna prototype is in progress and experimental results will be presented during the conference.

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