Pattern Reconfigurable Slot Antenna Array

Alexis MARTIN, Vincent LE NEILLON, Mohammed HIMDI
Institut d'Electronique et de Télécommunications de Rennes, IETR UMR-6164 / Université de Rennes 1, Rennes, France
alexis.martin@univ-rennes1.fr

Abstract **– In this paper, an antenna with reconfigurable radiation pattern in H-plan at 2.45 GHz for high power applications is presented. It is based on a 3 slots array in E-plane covered partially with two mobile metallic flaps in order to reduce their length and in consequence they ensure the mechanical reconfiguration pattern in H-plane. The power distribution of the array is ensured with a power splitter in E-plane and the field distribution on the slots is ensured with a sectorial horn placed before the splitter.**

Index Terms **— Mechanic, radiation reconfigurability, high power microwave, sectorial horn, power splitter, metallic flaps**

1. Introduction

High Power Microwave (HPM) antennas are well suited for high pulsed power application [1] like no lethal weapon or drones interception. In this field of applications, antennas must provide good efficiency low losses and low back side radiation. Radiation pattern control and especially Half Power Beamwidth (HPBW) reconfiguration is important to focus only on the target. However, there is a challenge to maintain a suitable power handling with high reconfiguration pattern.

Two particular ways were proposed to design reconfigurable radiation pattern with variable HPBM. The first one is based on a high power electronic device to electronically control the radiation pattern [2]. Another way is to use a mechanical system as in [3] with a defocusing system on a parabolic antenna.

In this paper, an H-plane mechanically actuated radiation pattern antenna is presented. The HPBW reconfiguration between 20° and 45° is provided by physically moving two parasitic flaps. The E-plane pattern is fixed by a 3 slots array distributed by an E-plane power splitter [4] after a sectorial horn. The antenna design concern the radiation but also the good matching in all reconfiguration cases. A set of measurements including reflection coefficient and radiation patterns is presented, and compared to the simulation.

2. Antenna Design

The proposed antenna is based on a sectorial horn antenna radiating aperture with the illustrated uniform E-Field amplitude and phase distribution (Fig. 1). The objective of the design is to mechanically change the physical aperture length in order to obtain the reconfigurable radiation pattern in the H-plane. According to (1) [5] the mathematical relation between the physical aperture length and the corresponding HPBW ($\theta_{H(-3dB)}$ in degrees) can be expressed approximately as follow (for uniform electric field distribution along the aperture):

$$\theta_{H(-3dB)} \approx \lambda_0 \times 180/(a \times \pi) \quad (1)$$

Where λ_0 is the wavelength in the free space and a the length of the aperture. In order to be compliant with a HPBW variation in the H-plane from 20° to 60°, it is deduced that the antenna's aperture length a should evolve from 351 mm to 117 mm respectively (at 2.45 GHz). In this design the length has been fixed to 400mm.

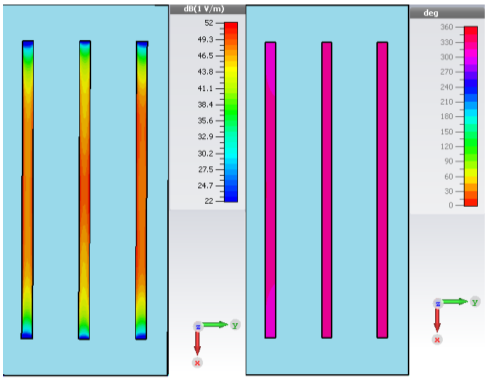

Fig. 1. Radiating aperture with the E-Field amplitude and phase distribution

To provide the constant amplitude and phase distribution along an aperture, an H-plane sectorial horn is used as a feeder. The length of the horn is fixed to 390 mm to guarantee the phase constant. In order to keep the E-plane beamwidth to 30°, three slot array with inter-element distance equal to 0.6λ_o at 2.45 GHz were used.

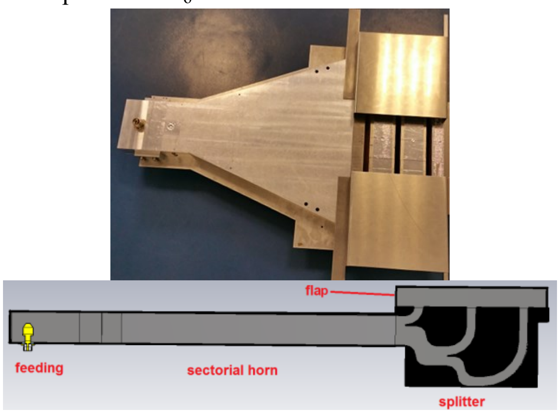

Fig. 2. Global design of the antenna

To provide the amplitude and phase distribution to each aperture (E-plane), a power splitter in the E-plane is used after the horn. The global design is presented on Fig. 2.

The detail of the power splitter is presented on Fig. 3. To design it, an optical approach is first used to theoretically determine the dimensions. To provide the same phase in all apertures, we must have:

$$v_1\times \pi/2+\lambda_0=v_4\times \pi+l_1+v_2\times \pi/2+l_3 \quad (1)$$

$$v_1\times \pi/2+2\lambda_0= 2v_4\times \pi+l_1+l_2+v_3\times \pi/2+l_4 \quad (2)$$

Then, with the physical constraints (space between apertures d and level of apertures) we obtain:

$v_1+d=v_2+l_1+2v_4$ (3), $v_1+b+2v_4-b_1/2=l_3+v_2+b_3+b_2/2$ (4)

$v_1+2d=v_3+l_2+l_1+4v_4$ (5), $v_1+b+4v_4-b_1/2 =l_4+v_3+b_3/2$ (6)

b parameter is the width of the waveguide at the input of the horn (b=43.18mm). Resolution of this system gives:

$$l_1=[2b+d (\pi-2)-b_2-b_1-2(b_3+\lambda_0-4v_4)]/(\pi-4) \quad (7)$$

$$l_2=[d (\pi-2)+b2+b3-2(\lambda-4v4)]/(\pi-4) \quad (8)$$

$$l_3=[2b(\pi-2)+4d-b_1(\pi-2)-b_2(\pi-2)-2b_3(\pi-2)-4\lambda_0+8v_4(\pi-2)] /[2(\pi-4)] \quad (9)$$

$$l_4=[2b(\pi-2)+8d-b_1(\pi-2)-b_3(\pi-2)-8\lambda_0+16v_4(\pi-2)]/[2 (\pi-4)] \quad (10)$$

$$v_2=[-2b-2d+b_1+b_2+2b_3+2\lambda_0+v_1(\pi-4) -2\pi v_4]/(\pi-4) \quad (11)$$

$$v_3=[-2b-4d+b_1+b_3+4\lambda_0+v_1(\pi-4) -4\pi v_4]/(\pi-4) \quad (12)$$

b_1, b_2 and b_3 are fixed to b/3. We fixed arbitrarily v_4=b/3 to have a positive solution for each parameters.

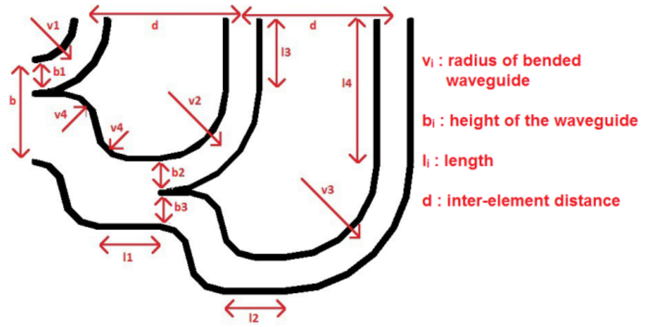

Fig. 3. Design of the power splitter

The mobile metallic flaps are place above the radiating apertures at a distance h=λ_0/4 to minimize their influence on matching. Finally, we fixed $v_1=\lambda_0/(2\pi)$ to have the wave from the first aperture reflected toward the flap that come back on the splitter to radiate in phase.

3. Simulation and Measurements

The simulation was performed on CST Microwave Studio. Fig. 4 presents de return loss of the antenna for different values of the distance between the two flaps l_f. There is a small frequency shift between simulation and measurement (10 MHz). The antenna is adapted (S_{11}<-10 dB) for l_f between 400 mm (no flaps over the apertures) and 150 mm.

Measurement of the radiation pattern was performed on an anechoic chamber at 2.44 GHz on both E-plane (Fig. 5) and H-plane (Fig. 6). At this frequency, the antenna present the best matching compared to 2.45 GHz in simulation.

A good agreement can be observed between simulation and measurement, only small shift on frequency.

The radiation pattern in the E-plane doesn't change when the flaps move with a HPBW of 30° and side lobe level below -10dB. On the H-plane, the HPBW changes from 18° (flaps opened l_f=400 mm) to 44° (flaps closed l_f=150 mm) with side lobe levels below -15 dB. The gain varies between 13 dBi to 18 dBi. Fig. 7 summarizes these results, showing the gain and the HPBW versus l_f.

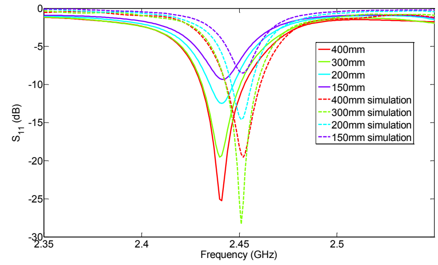

Fig. 4. Simulation and Measurement of the return loss

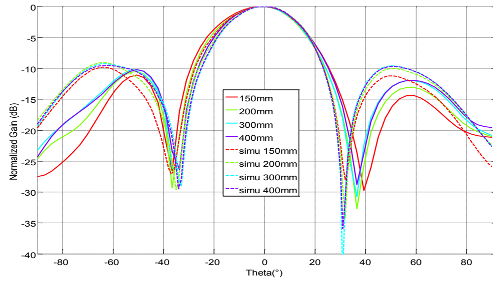

Fig. 5. E-plane Radiation pattern

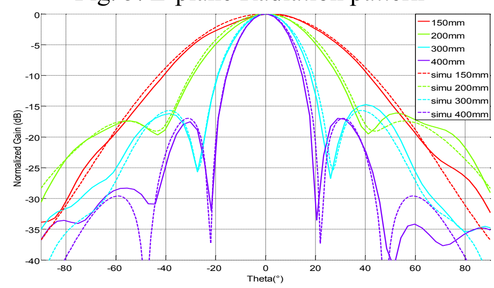

Fig. 6. H-plane Radiation pattern

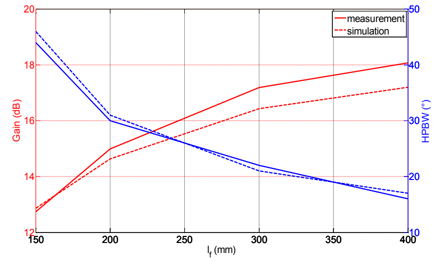

Fig. 7. Gain and HPBW versus lf

4. Conclusion

A high power pattern reconfigurable antenna has been designed with a sectorial horn and a power splitter coupled with a mechanical metallic flaps. The radiation pattern is constant in the E-plane (HPBW of 30°) and changes in the H-plane (HPBW from 18° to 44°).

References

[1] X. Li, Q. Liu, and J. Zhang, "Design and application of high-power cavity-backed helical antenna with unit ceramic radome," Electronics Letters, vol. 51, no. 8, pp. 601–602, 2015.

[2] M. Caillet, O. Lafond, M. Himdi, "Reconfigurable Microstrip antennas in Millimeter Wave," in Proc. 2006 IEEE MTT-S Int. Microwave Symposium Dig, pp. 638-641, June 2006.

[3] A. D Olver and J. U I Syed, "Variable beamwidth reflector antenna by feed defocusing," *Microwaves, Antennas and Propagation*, IEE Proceedings, vol. 142, no. 5, 1995.

[4] F. Arndt, et all "Optimized E-Plane T-Junction Series Power Dividers," IEEE Transactions on Microwave Theory and Techniques, vol. 35, no. 11, pp. 1052–1059, Nov. 1987.

[5] A. Balanis, Antenna theory, 3rd ed, Wiley-interscience, 2005, pp. 671-673.