Pillbox Antenna Integrating Amplitude Monopulse Technique in SIW Technology

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***Abstract* - A novel pillbox antenna integrating monopulse amplitude comparison technique is presented. The monopulse operation is realized in the antenna scanning plane i.e., E-plane. This enhances the angular resolution in this plane and avoids the mechanical orientation of the antenna. The proposed concept has been validated by a prototype in SIW (Substrate Integrated Waveguide) at 24 GHz. The prototype is currently under measurement. The numerical results show very good performance over an angular sector of ±26° for the Σ and Δ patterns. The SLL is lower than -25dB for the central Σ beam and is around -10dB for the extreme Σ beam position. The antenna gain ranges between 22dBi and 24dBi and the null depth for all the Δ beams is lower than -30dB.**

***Index Terms*—Multi-beam antenna, amplitude comparison monopulse technique, Pillbox antenna, Substrate Integrated Waveguide (SIW).**

1. Introduction

In classical monopulse systems the antenna boresight is steered to the target location by mechanical orientation of the full structure. This creates slow response time due to the mechanical inertia of the antenna system. To overcome this limitation, various antenna solutions have been proposed [1]-[3]. In particular, the monopulse antenna in [3] operates as a phase interferometer system for each radiated beam. It combines the scanning capabilities of the pillbox antenna [4] with the phase monopulse technique in the plane orthogonal to the scanning plane i.e., in H-plane.

It the present paper we investigate the possibility of integrating the monopulse amplitude operation in the scanning plane. The Σ and Δ patterns are generated in the same plane i.e., in the E-plane with an appropriate feeding system. An exploded view of the proposed antenna concept is shown in Fig. 1.

This paper is organized as follows. Section 2 describes the antenna system and its mode of operation. Simulation results are provided in section 3. Conclusions are drawn in Section 4.

2. Antenna configuration and mode of operation

The antenna shown in Fig. 1 is a dual-layer structure. In the lower layer (Sub.1) lies the feeding system composed of five horn pairs numbered from #1 to #5 and located in the focal plane of an SIW integrated parabolic reflector. In the upper layer (Sub.2) lies the radiating part which is a slotted waveguide array. The two layers are coupled by a quasi-optical system composed of an integrated reflector and several coupling slots [4].

Each horn pair in the feeding system (refer to Fig. 1) is composed of two H-plane sectoral horns connected to a coupler cascaded with a delay line, serving as a monopulse comparator. Each pair has two ports; the Σ and the Δ port and for each port corresponds a radiation pattern in the far field region.

The antenna mode of operation can be explained by considering the central horn pair in the emission mode:

- When port 3(Σ) is excited, the coupler cascaded with the delay line produces an in-phase excitation for the two connected feed horns. The corresponding radiated beams add in phase, leading to the Σ beam.
- When port 3(Δ) is excited, the two feed horns are excited out-of-phase. The radiated beams cancel out in the boresight direction (broadside direction for the central horn pair), thus generating the Δ pattern in the elevation plane (E-plane).

The antenna operates in a similar way for the offset horn pairs.

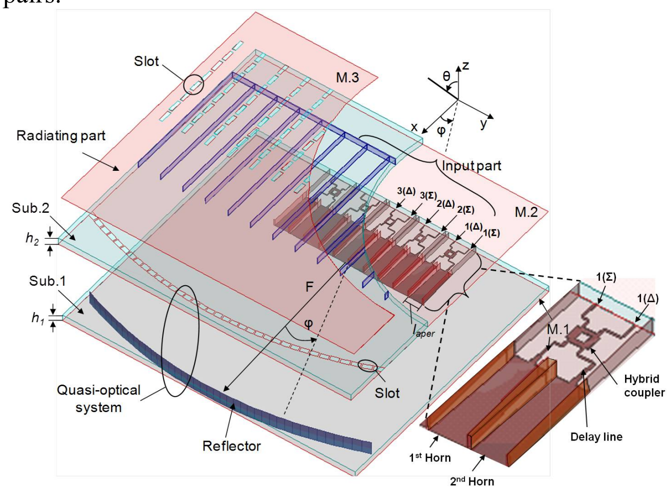


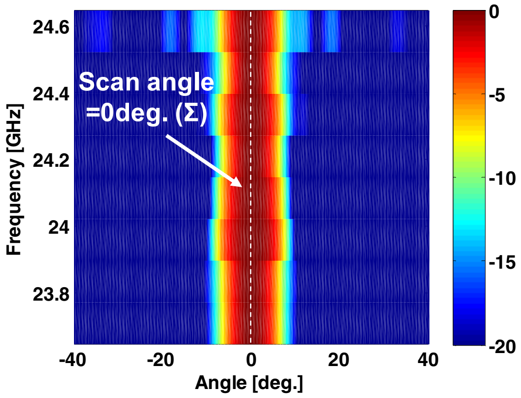
Fig. 1. Exploded view of the amplitude monopulse pillbox antenna.

3. Results

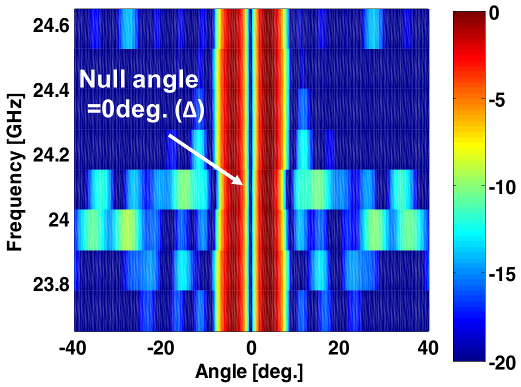
The antenna has been designed in SIW technology and optimized at 24.15 GHz. For its fabrication standard PCB fabrication process has been used. The two substrates (Sub.1 and Sub.2) are Rogers 5880 (ε_r=2.2) bonded with a "Speedbord" bonding film. The total thickness of the antenna stack-up is around 1.2mm. The realized prototype is currently under measurement at IETR, France. Therefore, we only provide the numerical results performed with Ansys HFSS version 14.

(1) On-axis radiation performance

The 2D radiation patterns in E-plane for the Σ and Δ ports of the central horn pair are plotted in Figs 2.a and 2.b, respectively.



(a) Σ pattern



(b) Δ pattern

Fig. 2D radiation patterns in E-plane. The scale in the right is in dB.

The shape of Σ pattern is stable and independent of frequency as well as the scanning angle within the frequency band of interest ([23.65-24.65] GHz). Similar behavior is observed for the shape of the Δ pattern and the angular position of the null of the radiation pattern. The stability of both radiation patterns is due to the True Time Delay (TDD) behavior of the pillbox transition. The null depth for the Δ pattern is lower than -30dB. Note that similar performance is obtained for the remaining offset horn pairs (not shown for space limitation).

(2) Off-axis radiation performance

The simulated radiation patterns for all the Σ patterns in E-plane at 24.15 GHz are shown in Fig. 3.

The antenna field of view is up to ±26° thanks to five Σ ports of the feeding system (Fig. 1). The side lobe level is lower than -25dB for the central Σ port and is around -10dB for the extreme Σ beam position. All beams are mutually orthogonal and the crossover level is around -9dB. The scan loss for the last beam position is around 2dB. At the design frequency, f=24.15 GHz, the antenna gain for Σ patterns ranges between 22dBi and 24dBi depending on the feed horn pair. The fractional bandwidth for VSWR<2 equals 2.8% for both the Σ and Δ ports. This bandwidth is limited by the resonant nature of the radiating part i.e., slotted waveguide array of resonant type. The isolation between the Σ and Δ ports in the same horn pair is better than 22dB in the considered frequency band for all horn pairs. More details about the antenna design and results will be provided during the conference.

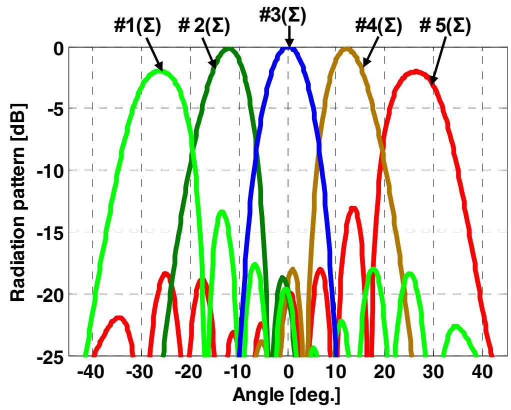


Fig. 3 Radiation patterns in the antenna E-plane at 24.15 GHz for the Σ patterns.

4. Conclusion

A new SIW pillbox multi-beam antenna implementing the amplitude comparison monopulse technique has been proposed in the 24-GHz band. In phase and out of phase excitation of the horn pairs, in the focal plane of the pillbox transition, form the Σ and Δ radiation patterns in the scanning plane of the pillbox antenna. This increases the angular resolution of the antenna system, and avoids any mechanical rotation of the antenna. Very good performance has been obtained in simulation. The Σ and Δ patterns are stables and independent of frequency thanks to the TDD behavior of the pillbox transition.

The antenna prototype has been fabricated with standard PCB fabrication process and is currently under the measurement.

References

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