# Design of Single Radiator Direction Finding Antenna Using SIW Feeders


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***Abstract* - This paper proposes a multimode substrate integrated waveguide (SIW) feeding system with a single patch antenna for monopulse direction finding applications. The multimode feeding system allows to radiate the sum and difference patterns with a single radiator. The maximum gains of each sum and difference pattern are 2.1 dBi and –2.6 dBi, respectively. We then obtain a calibration factor that minimizes the RMSE of the angle of arrivals to 2.1°.**



***Index Terms* – Monopulse direction finding, Multimode feeding system, Single radiator monopulse system**


## I. INTRODUCTION

Until recently, monopulse systems for direction finding have been widely used in various military applications, such as radars, aircrafts, and low-cost missiles. Particularly, in low-cost missile applications, the monopulse system requires inexpensive fabrication cost, lightweight, and compact size since the system mounted on a missile warhead is disposable and used for a single explosion [1]. In order to obtain these features, the radiators and feeding networks of the monopulse system should be small in size with a simple fabrication process. However, conventional monopulse systems typically include four radiators and complicated comparators to derive sum and difference patterns for the detection of the signal direction [2]. To overcome these shortcomings, some researches use a microstrip patch antenna as a radiator or use a substrate integrated waveguide (SIW) feeding network as a comparator [3,4]. Although such studies have reported improved monopulse performance in direction finding, the complexity of multiple radiators and feeding networks still make it difficult to apply these systems for commercial wireless communications such as BLE, RFID, and Wi-Fi.

In this paper, we propose a SIW multimode feeding system with a single radiator for the monopulse direction finding. The multimode feeding system can guide the fundamental and high-order modes to generate the sum and difference patterns. The radiator for the monopulse system is simplified with a single printed patch antenna instead of the multiple radiators. The calibration factors are then obtained to compensate for the sum and difference pattern distortions, which can be used to more precisely estimate the angle of arrivals for the proposed monopulse system.

## II. DESIGN AND PERFORMANCE OF THE PROPOSED ANTENNA

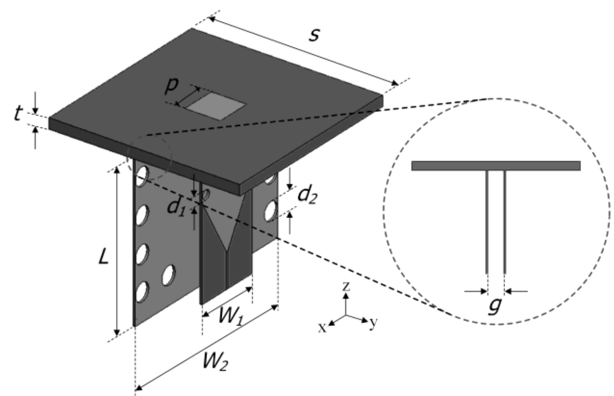


Fig 1. Geometry of the proposed monopulse antenna

Fig.1 shows the geometry of the proposed multimode feeding system with a single radiator for the monopulse direction finding. The feeding system has two SIW transmission lines excited by the microstrip lines, which is a lightweight and simple structure in fabrication compared to a conventional monopulse feeding system. In order to better guide the fundamental ($TE_{10}$) mode and high-order ($TE_{20}$) mode waves, the SIW vias have diameters of $d_1$ and $d_2$ as well as widths of $w_1$ and $w_2$. These feeding systems are directly connected to the single patch antenna with a gap of *g* [5]. The rectangular patch, printed on FR-4 substrate with a width of *p* and a height of *t*, is a single radiator used instead of the conventional multiple radiators. The detailed design parameters are listed in TABLE I.

TABLE I
PARAMETERS OF THE PROPOSED ANTENNA

| Parameters | $w_1$ | $w_2$ | $d_1$ | $d_2$ | $g$ | $p$ | $t$ |
|---|---|---|---|---|---|---|---|
| Values (mm) | 50.8 | 144.6 | 7 | 13.4 | 10 | 26.9 | 8 |

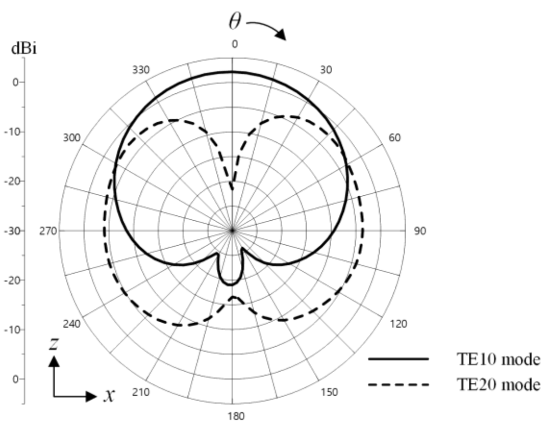


Fig 2. 2D radiation patterns of the proposed antenna

Fig. 2 presents 2D active element patterns (AEP) of the proposed monopulse antenna in the *zx*-plane when using the $TE_{10}$ and $TE_{20}$ mode feedings, respectively. The maximum gains of the $TE_{10}$ and $TE_{20}$ modes are 2.1 dBi and –2.6 dBi in the upper hemi-sphere. The patterns using a single radiator with the multimode feeding system have the similar sum and difference patterns to the conventional monopulse system.

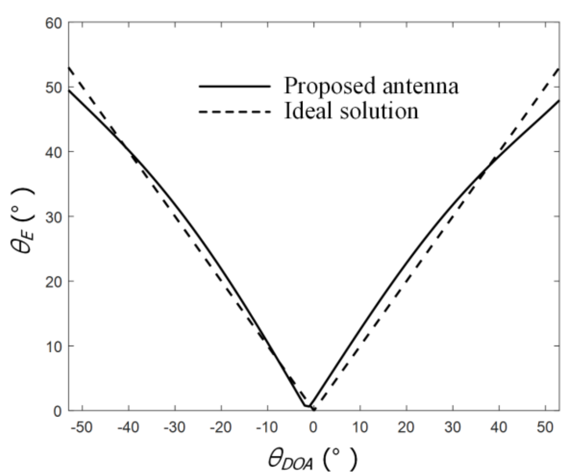


Fig 3. Estimated angle using the sum and difference patterns

Fig. 3 represents the comparison of the estimated angles between the proposed antenna indicated by the solid line and the ideal solution with the dashed line according to the direction of arrivals (DOAs). Due to the distortions in the sum and difference patterns, the sum-difference ratio of the proposed antenna is then compensated by calibration factors. Two calibration factors ($k_1$ and $k_2$) are determined for both left ($\theta < 0°$) and right ($\theta \geqq 0°$) directions to minimize the root-mean square error (RMSE) of the estimated angles. Through this compensation, the proposed antenna has an RMSE of 2.1° when calibration factors $k_1$ and $k_2$ are 1.04 and 0.92, respectively.

## III. CONCLUSION

In this paper, we proposed the multimode SIW feeding system with a single radiator for the monopulse direction finding. The multimode feeding system with lightweight and simple structure can radiate the sum and difference patterns using the single printed patch antenna. The maximum gains of each sum and difference pattern are 2.1 dBi and –2.6 dBi. The proposed antenna shows an RMSE of 2.1° when the calibration factors $k_1$ and $k_2$ are 1.04 and 0.92.

## ACKNOWLEDGENT

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