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# A Low-Cost Combination for Phased Array and ESPAR Antennas

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***Abstract*—a low-cost antenna system with high directivity is presented, with possibility of shaped beam in the vertical plane and beam switching in the horizontal plane, ensuring full 360 degrees coverage. The proposed antenna provides a higher directivity than the pattern of a regular Electronically Steerable Parasitic Antenna Radiators (ESPAR) while remaining much simpler than a phased array. The antenna system is made of two concentric rings, each consisting of 6 elements. Only three elements are active at a given time, the others are terminated with the reactive loads. The feeding and command structures are particularly simple. The proposed antenna is fabricated and measured for its performance.**

***Keywords—ESPAR, high-gain, switched beam, antenna arrays, active and passive elements, shaped-beam, localization.***

## I. Introduction

Modern telecommunication applications require low-cost customized antenna systems. More specifically, for asset tracking, angle of arrival estimations, and real-time positioning, shaped switched-beam radiation patterns are essential. In view of that, the proposed antenna system provides high directivity gain (around 12 dBi) and offers the possibility of beam shaping in the vertical plane and beam switching in horizontal plane to cover the whole field of view. Such needs may be covered with a phased array [1], which however is often too complex and costly for the envisioned applications. There have been some works in the area of high-gain switched-beam antennas. The authors of [2] explain how an antenna system (broadly antenna arrays) based on the ESPAR concept can be useful for such purpose, however the achieved gain is limited to 7 dBi. Other works include 25 wire antennas to achieve a similar gain of 12 dBi [3], a switched-beam radiator with maximum gain of 8.2 dBi [4], a high-gain microstrip antenna with parasitic elements allowing 360 degrees steering capabilities with a reported peak gain of 10 dBi [5], and a switched-beam antenna for drone communications with maximum gain of 6.4 dBi [6]. However, either they do not address beam shaping of any kind or/and they are not always cost effective to implement. Hence, antenna systems having high-gain with the possibility of beam switching with the possibility of some form of shaped beam while keeping the development cost low remains a research topic.

We propose here an antenna system that provides a directivity around 12 dBi, which is higher than with the standard ESPAR [2]. Besides, the antenna can be developed with low complexity as compared with active phased arrays [1]. The proposed antenna, named hereafter as PASHA (Parasitic and Active Switched-beam high-gain Hybrid Antenna), is controllable through purely electronic means. Only 12 monopoles are used, while only 3 elements are active at a time.

The remainder of this paper is organized as follows. Section II provides the antenna design, electronics control, and obtained results. Finally, conclusions are addressed in Section III.

## II. Antenna Design and Measurment

### A. Antenna design and Prototyping

The proposed antenna has been destined to tracking and localisation purposes, considering that the antenna is installed on a ceiling. It has been developed for RTLS Z-MOBILE (a Real Time Localization Application from MULTITEL [7]), based on standard IEEE802.15.4/Zigbee, to exploit the angle of arrival of RF signals upon propagation in complex environments (indoor, outdoor, and open space). The state-of-the-art antenna has been filed for patenting [8]. The beam is shaped to ensure a good reception at the level of a person's chest when the distance "x" varies in a range associated to ϴ from 18 to 30 degrees, as shown in Fig. 1. In addition, the antenna radiation beam should be azimuthally rotating to cover the movements of objects containing the RF tags. An overlap between patterns ensures a continuous localization without a blind spot when the tag moves on the perimeter around the antenna.

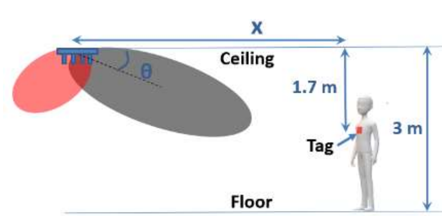


Fig. 1. Application Scenario of the PASHA Antenna for localization purpose. (human model drawn with Microsoft 3D paint).

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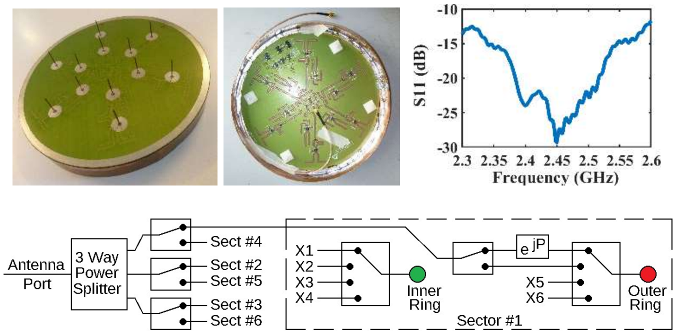


Fig. 2. Top left**:** Front view of antenna. The ground skirt has a depth of 2.9 cm. Diameter of outer and inner ring are 17.25 cm and 8.625 cm, respectively. The diameter of full antenna ground plane is 26 cm. The length of matched monopole is 2.6 cm. Top middle**:** back view with printed switching circuits. Top right**:** the measured S-parameter of a matched monopole. Bottom**:** global illustration of reactance (X) switching and phase related excitation. Six such arrangements are required as printed on the back.

The proposed antenna array is made of two concentric rings, each consisting of six matched monopoles as shown in top left and middle of Fig. 2. A close antenna spacing allows strong mutual coupling within the inner ring, able to act as a reflector w.r.t. the three active elements located on the outer ring. This specific arrangement provides enhanced gain with a strongly limited number of active elements. The active monopoles are excited from a common signal, with different phases. The beam tilt-angle to shape the pattern in elevation is adjusted by properly designing the skirt of the ground plane and the antenna elements with proper reactance loading. The rotating beams can be obtained by switching and changing the antenna excitations and reactive load terminations. The switching arrangement is given in bottom diagram of Fig. 2. The phase angle "P" is a position-related phase shift that affects elements 1 and 3 of the active monopoles and is given with respect to element 2. The value of P is found to be 108.8 degrees to create a maximum of radiation at an angle around 22 degrees from the array plane. The switching operation time is very low (below 1 microsecond), allowing a very fast pattern rotation. As such, the design is able to provide a combined effect of ESPAR and phased array ideas, with only 3 active elements and only electronically controlled switchable structures (no phase shifters). For an accurate realization, a careful de-embedding of transitions and switches has been carried out.

### B. S11 and Pattern Measurement

The measured values of the reflection coefficient (S11) at the input of the cable of the antenna are shown in top right of Fig. 2. The antenna has a center frequency around 2.44 GHz with an impedance bandwidth of more than 80 MHz—the required application bandwidth by the system. The simulated and measured radiation pattern are presented in Fig. 3 via the self-illustrated text in figure caption. One can also note the overlap between two adjacent beams, which avoids blind zones. The other beam positions and frequencies have similar patterns and are not presented here for brevity purposes. A measured directivity gain in the direction of maximum radiation assures at least 12 dBi from 2.415 to 2.475 GHz, and 11.57 dBi at 2.4 GHz and 11.82 dBi at 2.48 GHz.

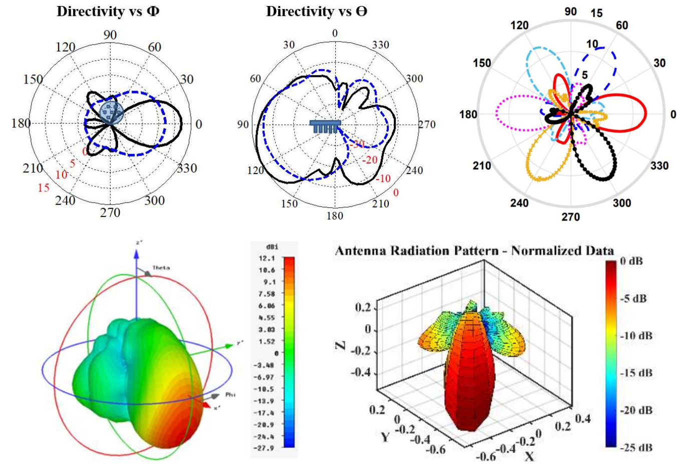


Fig. 3. Simulated and measured 2D and 3D radiation patterns at 2.44 GHz: Top left: Horizontal plane, Top middle: Vertical plane. Broken blue curves represent the reference ESPAR patterns. As a reference, the 7-element standard ESPAR comprises of 1 active element at the center and is surrounded by a ring having 6 reactively loaded passive elements. Top Right: Measured switched beam radiation patterns (at six different positions) in horizontal plane. Bottom left: Simulated 3D pattern, Bottom right: Measured 3D Pattern at one beam position. All the simulations are carried out using CST microwave studio [9].

## III. Conclusion

The main advantage of the proposed antenna is its simplicity of implementation and low cost. The proposed antenna is considered minimal as a hybrid solution is proposed in which design of phase, active and passive elements (with their loads), and ground skirt provides specified antenna characteristics. The radiation patterns are stable over the required application bandwidth of 80 MHz. Moreover, in addition to the radiation performance optimization role played by the metallic skirt, it can also act as a heat-sink for the electronic components.


## Acknowledgment

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