# E-Shad Microstrip Patch Antenna for Search and Rescue Transponder (SART) Applications

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## Abstract

This paper presents the design and simulation of an E-shaped and shorting pin via hole between ground and exciting microstrip patch antenna intended for use in Search and Rescue Transponders (SART). The antenna is designed to operate within the 7.2-7.3 GHz, 8.8- 10.5 GHz and 11.3- 13 GHz frequency range, complying with IMO and GMDSS regulations. The E-shaped configuration is chosen for its enhanced bandwidth and gain characteristics over conventional rectangular patch antennas. The proposed design is simulated using IE3D, and key parameters such as return loss (S11), gain, directivity radiation pattern, and VSWR are analyzed. The proposed antenna is achieved the power transfer gain from 2,5 to 3.5dBi. The VSWR for a band is ranging from 1 and the return loss S11 for this band is -36 dBi. The results show that the E-shaped patch antenna meets the operational requirements for reliable SART communication in maritime emergency conditions.

**Keywords:** E-shaped patch antenna, microstrip antenna, SART, search and rescue, high gain, radar band.

## . Introduction

Search and Rescue Transponders (SART) are critical safety devices used in maritime navigation to locate distressed vessels. These devices operate in the C and X-band frequency range, particularly between 7.2 GHz to 7.3 GHz, 8.8 GHz to 10.5 GHz and 11.3 GHz to 13 GHz must have high reliability, sufficient gain, and wide bandwidth to ensure visibility to radar systems.

The patch antennas are favored in such applications due to their lightweight, low profile, and ease of integration. However, traditional rectangular patch antennas suffer from narrow bandwidth, making them unsuitable for applications requiring wide frequency coverage. The E-shaped patch antenna, a modified form of the rectangular patch, offers improved bandwidth and gain performance, making it ideal for SART systems. The antenna are differentiated for variety of uses in the wide frequency range [1]. Due to tiny and light weight of an antenna and high performance it is used in a radar system. [2] satellite communication [3] mobile communication and other application where the light and compact size antenna is required.[5] In a navigation and for large distance water environments such light weight antenna is to be used and it is useful in a search and rescue transponder (SART) to improve performance. In life intimidating conditions is easy to solve in between aground people and rescue crew in a critical SART[6] are crucial SARTs [7], which is work on the operating in the range of 9.2-9.5 GHz X band [8], The SART system are used in bad weather and where to operate in some of the most difficult places like interference prone maritime, stormy sea, high humidity situation[9], the antenna used in a SART system is X band [10], the author use to design a unique SART system antenna to operated in a limited space for maritime operation.[11], the unique heart shape antenna design for stable radiation pattern to improve beamwidth and directivity[12] the author discuss about maritime rescue operation[13], the SART system working on different dielectric substrate [14], the SART system operated in very high gain and used in X band [15], The design is used circular and rectangular patch to improve the performance [16] the square shape antenna with a dimension of 40x40x16mm with a substrate of Fr4 is used to improve the bandwidth [17]. The author is used impedance matching technique to improve the performance, reducing power between the antenna radiating patch antenna and ground plane used of diamond shape [18], the antenna is suitable for high efficiency is used to reduced the signal loss due to humidity and water[19], used of different class of substrate for a SART system to improve the performance of antenna[20],Work on humanity, sea water to improve the performance of an antenna used as a heart shape microstrip patch antenna. [21] present a heart shape antenna used as a conventional antenna for maritime rescue. This study finding the communication system for high gain, high efficiency and stable radiation pattern, the study shown the simulation, fabrication and testing of the antenna in X band.

# 2. Antenna Design

**2.1** As shown in Fig.1 the proposed antenna E shape is printed an exciting patch and rectangular ground plane. The changing the position of via hole and E slot, we can easily resonance the frequency. Here we the inductive or shorting the exciting patch and ground plane through open via pin for radiation patch is configure so that the fringing field that is more surface field into the load (free area). The proposed antenna is designed by using Fr4 substrate (εr = 4.4) with a thickness of 1.5mm. The dimension of an antenna is 18 x 14 x1.5 mm with a wavelength of 0.3λ

### Substrate Selection

- **Material**: FR4 (εr = 4.4)
- **Thickness (h)**: 1.5 mm
- **Loss tangent**: 0.02 (for FR4),

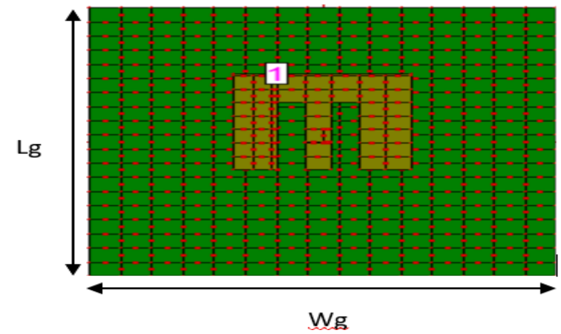


Fig:1 Proposed antenna with E slot at Exciting plane and simple rectangular patch at ground plane.

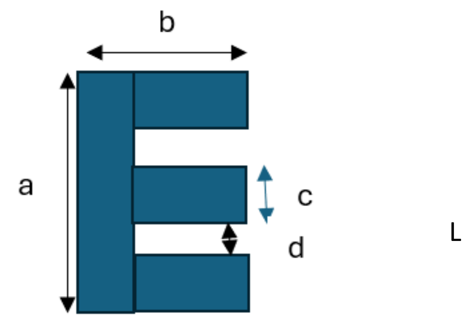


Fig 2: E slot printed on radiating plane

Table1 Design specifications [5]

| Parameters | (mm) | Parameters | (mm) |
|---|---|---|---|
| Lg | 14 | A | 3.5 |
| Wg | 18 | B | 3.5 |
| L | 5 | C | 1 |
| W | 9 | D | 0-5 |

Where Lg and Wg represent the length and width of ground plan. L (length) and W (Width) of the E slot for radiation in to the free space. a, b, c and d is the dimension as shown in figure 2. The probe feeding is used to match the impedance, and maximum field is transfer into the free space the probe feeding is generally connected through sma connector. The antenna is configured by using via hole connecting between ground and exciting patch. Table 1.[5] As shown above the different dimensions of the proposed antenna.

### 2.1 Substrate Selection

- **Material**: FR4 (εr = 4.4)
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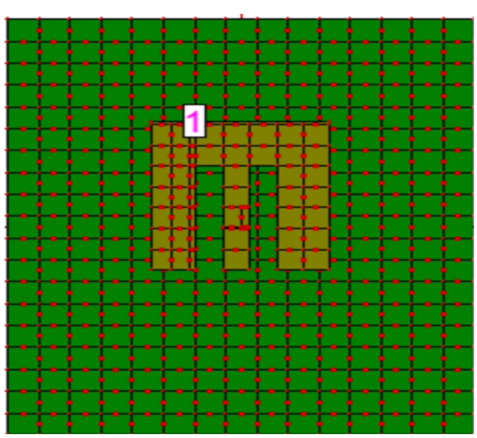
- 

### 2.2 Design Specifications

- **Operating frequency**: 9.2 – 9.5 GHz
- **Antenna Type**: E-shaped microstrip patch
- **Feeding Technique**: Coaxial probe or inset microstrip line
- **Patch dimensions**: Determined using transmission line and via hole model to optimized via simulation

### 2.3 E-Shaped Geometry

The E-shaped patch is formed by introducing two slots into a conventional rectangular patch. The slot dimensions and placements control bandwidth and resonance characteristics.



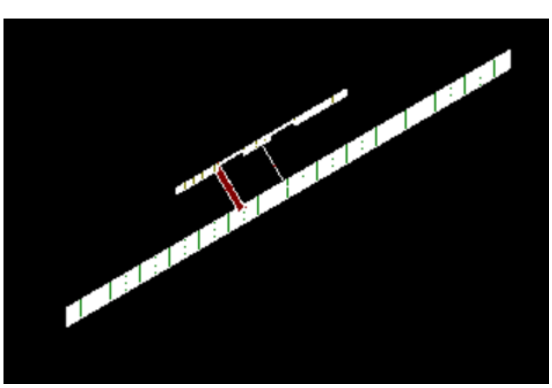



Fig 3.Top view and Side view of the proposed antenna

- **Length of patch (Lp)**: ~7 mm
- **Width of patch (Wp)**: ~9 mm
- **Slot length and width**: Optimized for multi-resonance

  **4Feed point location**: Optimized for impedance matching

## 3. Simulation and Results

### 3.1 Simulation Tool

The design was simulated using IE3D.

### 3.2 S-Parameter (Return Loss)

- Achieved S11 < –10 dB across 7.2 – 7.3GHz, 8.8 - 10.5 GHz and 11.3 – 13GH
- Resonant in three different band of frequency: ~7.2, 9.35 and 12 GHz

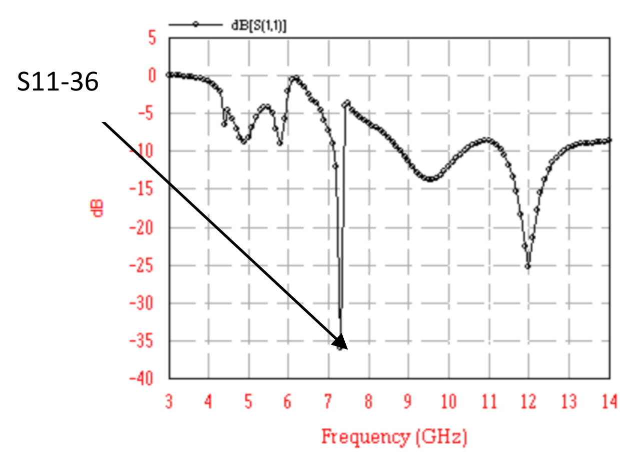



Fig 4. Dual band response with respect to frequency verses return loss

From Fig 3 it shows the return losses(S11) of the proposed antenna. The antenna radiates the signal in a three band in between 7.2-7.3 GHz, 8.8 - 10.5 GHz and 11.3- 13 GHz. The antenna parameter is optimized to operate in a SART band is used in a E shaped structure to achieve a impedance bandwidth of (S11 ≤ -

10dB) with inverted E shape and via hole of C and X band-band operation. The design is applicable only for three bands. S11 at -35dB frequency is 7.3 GHz, return losses at is -15dB frequency is 8.8GHz and -25dB at 12 GHZ. The variation in inverted E slot on the topmost of geometry the band may be change. Here we can change the band and improve the bandwidth of an antenna by changing the position or stub matching technique of slot cutting and position of inverted E shape plane. The addition via pin of dimension 0.5mm radius is used to more attract into the free space.

## 3.3 VSWR

- VSWR < 2 throughout the desired band, indicating good impedance matching.

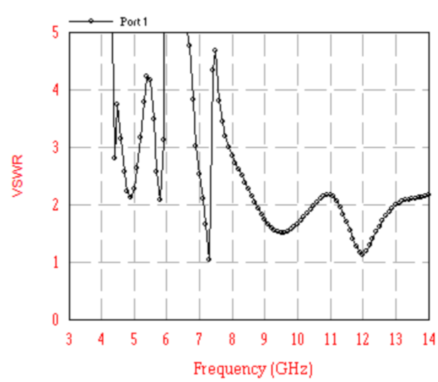



Fig 5. VSWR response with respect to frequency

As per graph the band which is achieved for SART application or C and X band application vary from 1 to 2. As shown in fig 5. It is observed that the impedance matching and maximum power transmitted by the range of VSWR is in between 1 to 2. As per graph the VSWR are 1 at 7.3 GHz and vary from 1 to 2 by varying the length of inverted E of the proposed antenna. From fig proposed antenna operated in three 7.2-7.3 GHz, 8.8- 10.5 GHz and 11.3- 13 GHz.

**3D View of proposed antenna**

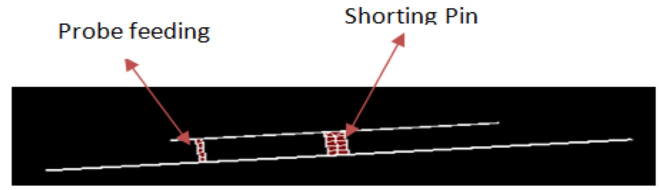



Fig 6: 3D View of proposed antenna with probe and shorting pin

As shown in Fig 6 the 3 D view of proposed antenna in this we used a via hole or compensated the inductive capacitive loading to resonance the frequency for maximum power transfer into the free space. The shorting pin 0.5mm diameter is used for resonance

## 3.4 Gain and Radiation Pattern

- Peak Gain: ~2–3 dBi
- Radiation Pattern: Broadside, linear polarization
- Beamwidth: ~60–90°

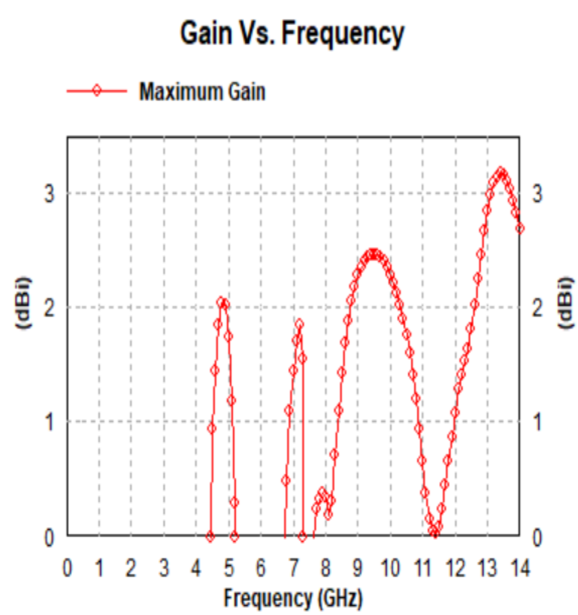



Fig 7. VSWR response with respect to frequency

As shown in fig 6 the gain vs frequency graph the gain is vary for C band ,X band and SART application is 2 to 3dBi. The gain is generally used in a antenna to radiate energy in a particular direction. As per graph such antenna is used in a point to point communication and other wireless applications.

**3D Radiation pattern and surface current of excited patch**

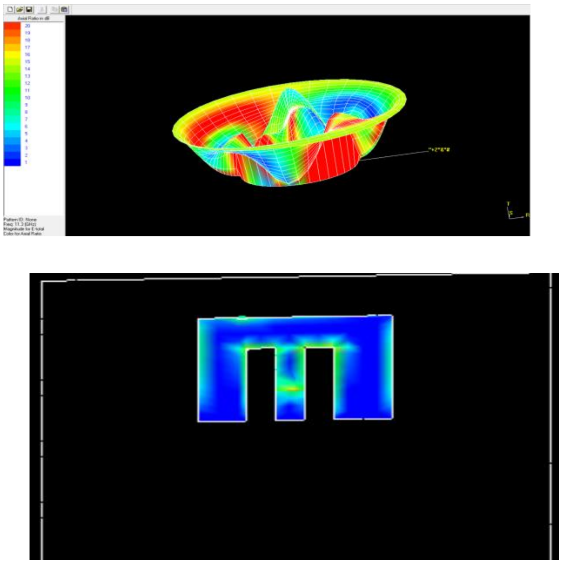


Fig 8: 3D radiation pattern and surface current of proposed antenna.

The 3D radiation pattern for three different band is as shown in a fig 8 the radiation pattern with a stable radiation pattern and gain is clearly represented in a pattern and surface current the color shown the maxixmum current transmitted into the surface the red blue combination indicted that the maximum current near the probe feeding and gradually decreases as they go away from the feeding point. So from fig it is clearly represented that the gain and polarization af an antenna is stable overall the 3D pattern of an antenna.

**E plane and H plane Radiation Pattern**

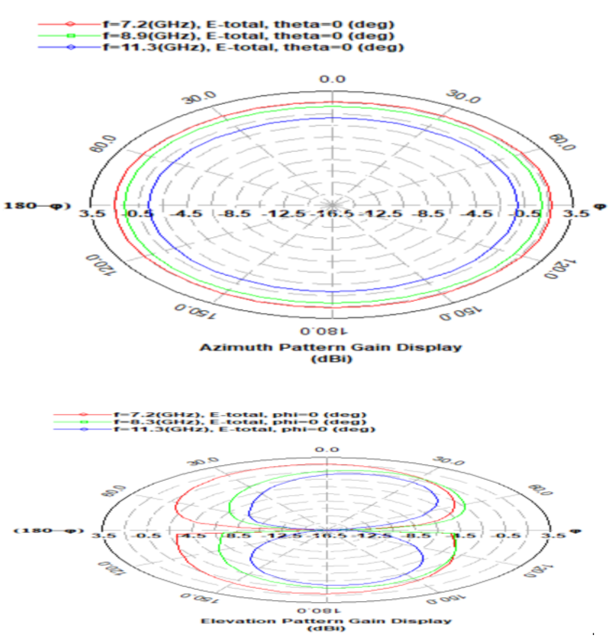



Fig 9: Azimuth and Elevation pattern of an antenna.

The antenna radiation pattern in term of azimuth (H Plane) and elevation angle (E Plane) is as shown in fig 9. Here the E plane and H plane radiation pattern for 7.2 GHz, 8.9 and 11.3 Ghz is presented. The antenna is used to enhance the antenna performance and to improve the maximum power transfer into the free space. The radiation is shown as figure of eight and figure of zero it is represented that the entire band is stable radiated into the free space and maximum transfer energy into the load

## 3.5 Directivity

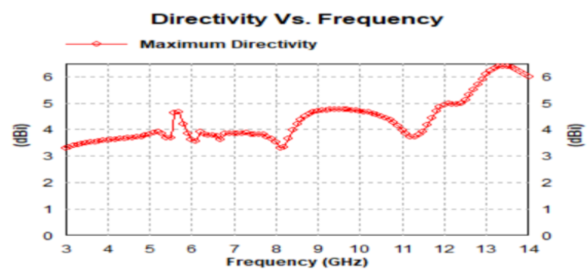



Fig 10: Directivity Vs Frequency of an antenna

As per graph and simulated result the directivity a proposed design is varied from 3 to 6dBi with respect to frequency. As shown in figure 10. The vary in three band is 4 Bi at 7.2 GHz, 5 dBi at 9.5 GHz and the directivity is approach maximum 6 dBi at 13 GHz. The directivity of an antenna is generally define with respect to beam area . if beam area is maximum then directivity is low. For improved the directivity we must work on beam area of an antenna.

## 3.6 Axial Ratio

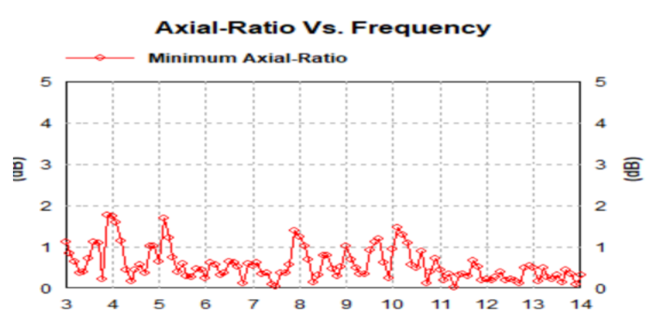



Fig 11. Axial Ratio of proposed antenna with respect to frequency

The axila ratio is vary from 1 to 2 and it is under 3dBi so it shown that the antenna is working as a linear polarization and also it shown that the antenna enhancing the perfomance by using the sloting structure. The Reactive impedance surface structure is used to obtined different Axial ratio point as shown in fig 11.

### 3.6 Bandwidth

- Bandwidth (–10 dB): ~100 MHz, 170 MHz and 170 MHz)
- Adequate to cover full SART operating band (8.8– 10.5GHz)
- For C band Application to cover (7.2-7.3 GHz)
- For X band Application to Cover (8.8 GHz-10.5 GHz) and 11.3 GHz- 13 GHz)

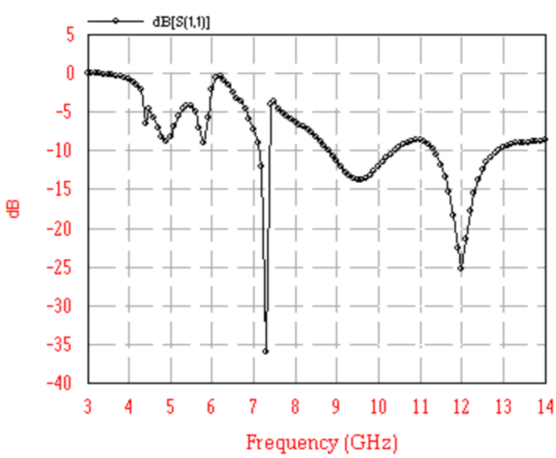



Fig 12. Bandwidth of proposed antenna with respect to frequency

# 4. Discussion

## Efficiency

The E-shaped patch effectively enhances bandwidth while maintaining compact size, making it ideal for handheld or vessel-mounted SART units. The improved gain ensures detection by radar systems even in rough sea conditions. Compared to a rectangular patch, the E-shape introduces dual resonances that combine to widen the bandwidth. The efficiency of antenna is approach approximately 70% and radiation efficiency approach the 80%.

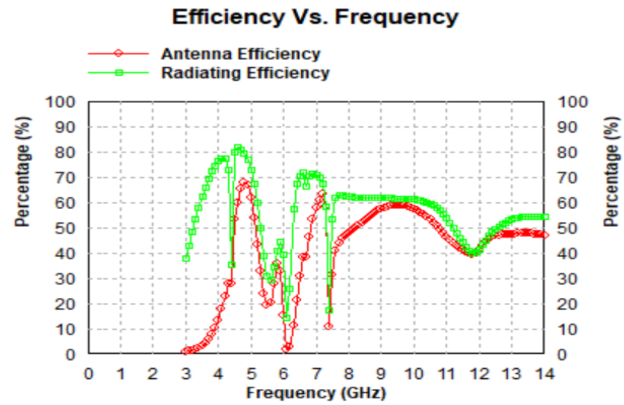



Fig 13. Antenna and radiation efficiency of proposed antenna with respect to frequency

# 5. Conclusion

An E-shaped microstrip patch antenna was successfully designed and simulated for C abnd X band and Search and Rescue Transponder applications in the 7.2-7.3GHz, 8.8 -10.5GHz and 11.3-13 GHz band. The proposed design meets key performance metrics such as bandwidth, gain, and VSWR, confirming its suitability for maritime emergency systems. Future work will focus on prototype fabrication and empirical testing to validate simulation results.

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