Microstrip Patch Antenna and Microstrip Patch Antenna Array for Microwave Life Detection System

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Abstract -The main problem during elimination of consequences of ecological accidents, connected with great destruction as earthquakes, failures, snow avalanche etc. is the rescue of people buried under fragments.Experience has shown that life detection systems like acoustic sensors are not reliable, and application trained dogs is not a universal means of capable to work under any conditions. The range of investigation of the optical endoscopes is limited by the opacity of the rubble.As a result, it appears that microwave sensors could bring some specific advantages for the detection of living victims. Primarily, microwaves are sensitive to small movements which are distinctive signs of life, independently of a possible loss of consciousness. It is at this juncture that microwave life detectors gain their significance [1] [2].The antenna system is an integral part of microwave life rescuing system. The compactness and portability of a microwave life detection system depend mainly on the miniaturization of the antenna used, which can be realised using a microstrip patch antenna. Microwave life detection system work in the L or X band. Since L band microwave signal penetrate large distance and is less affected by the presence of moisture compared to X band, it is better to use L band for life detection[2] . This paper proposes the design of a single element microstrip patch antenna and an 1x4 patch antenna array for a microwave life detection system at 2.45 GHz. The simulations are done in IE3D. Also the directivity of the simulated patch and Ix4 patch antenna array are compared. These antennas can also be used for various other applications in L band as WLAN, RF ID systems and other sensors.

Index Terms *-Microstrip Antenna, Microwave life detection system.*

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I. INTRODUCTION

In its most fundamental form, a Microstrip Patch antenna consists of a radiating patch on one side of adielectric substrate which has a ground plane on the other side as shown in Figure 2.7. The patch is generally made of conducting material such as copper or gold and can take any possible shape. The radiating patch and the feed lines are usually photo etched on the dielectric substrate [11].

1. Having a relative dielectric constant in the range of 1.0–2.0. This type of Material can be air, polystyrene foam, or dielectric honeycomb.
2. Having dielectric constant in the range of 2.0–4.0 with material consisting mostly of fiberglass reinforced Teflon.
3. with a dielectric constant between 4 and 10. The material can consist of ceramic, quartz, or alumina.

The advantages of the microstrip antennas are small size, low profile, and lightweight, conformable to planar and non planar surfaces. It demands a very little volume of the structure when mounting. They are simple and cheap to manufacture using modern printed circuit technology. However, patch antennas have disadvantages. The main disadvantages of the microstrip antennas are: low efficiency, narrow bandwidth of less than 5%, low RF power due to the small separation between the radiation patch and the ground plane(not suitable for high-power applications). Microstrip antennas are used not only as single element but also very popular in arrays. Main limitation of microstrip is that it radiate efficiently only over a narrow band of frequencies and they can’t operate at the high power levels of waveguide, coaxial line, or even stripline [2]. This can be minimized with the help of various array configurations, feeding methods, dielectric materials and ground planes. Antenna arrays are used to scan the beam of an antenna system, to increase the directivity, gain and enhance various other functions which would be difficult with single element antenna. In the microstrip array, elements can be fed by a single line or multiple lines in a feed network arrangement [3]. Based on their feeding method the arrays are classified as:

• Series feed network
• Corporate feed network
• Corporate-series feed network toolbar.

The most vital design of an antenna array is the feed network. This is constructed by first Connecting two adjacent elements together with a transmission line. Now two separate groups, each containing two elements, need to be connected together.

II. LITERATURESURVEY

Most of the victims of earthquake or other natural disasters in the various parts of the worlds are trapped under rubble of the collapsed buildings. A detection of the victims can save his life. As in the radar application, the phase of the incident wave can be changed due the body vibrations. Depending upon this fact Microstrip Antenna to Detect Human Being Buried under the Rubble used to trap the buried victims under earthquake rubble or collapsed buildings by the utilization of microwave radio frequency has been design.

The Microstrip Antenna for microwave life detection system can works on different range of frequencies from L-band (2GHz) to X- band (10GHz). But X- band microwave is unable to penetrate deep into the rubble. It can penetrate rubble up to 1.5 ft in the thickness (5 layers of bricks) while L-band can penetrate the rubble of about 3 ft in thickness (10 layers of bricks).Due to the fact that lower frequency will be more capable of detecting vital signs through very thick rubble, so frequency of an electromagnetic wave needs to be in the L-band or S-band range, For this reason, the a microwave life detection system which operates on the L-band frequency[3]. This system is supposed to quite efficient to trap the breathing and heartbeat signals of victims who are completely trapped and too weak to respond.

III. PROBLEM STATEMENT AND OBJECTIVE

Microwave life detection systems are effective in searching for human beings trapped under earth quake rubbles even if the rubble or debris covering the human victims is thicker than a few feet, especially for the case when the victims are completely trapped or too weak to respond to the signal sent by the rescuers. The antenna system is an integral part of microwave life rescuing system. The compactness and portability of a microwave life detection system depend mainly on the miniaturization of the antenna used, which can be realised using a microstrip patch antenna. The efficiency of the existing microwave life detection system can be raised by increasing the transmitted power, increasing gain of antenna, and by matching the antenna [1].Microwave life detection system work in the L, ISM or X band. Since L band and ISM band microwave signal penetrate large distance and is less affected by the presence of moisture compared to X band, it is better to use L band for life detection [2][8]

IV. SIMULATION OF A 2.4 GHZ PATCH ANTENNA FOR MICROWAVE LIFE DETECTION SYSTEM USING IE3D

4.1 Proposed Techniques and Methodologies

This paper proposes the design of a single element microstrip patch antenna and a 1x4 patch antenna array for a microwave life detection system at 2.4 GHz. The simulations are done in IE3D. Also the directivity of the simulated patch and 1x4 patch antenna arrays are compared. These antennas can also be used for various other applications in L band as WLAN (Wireless Local Area Network), RFID (Radio frequency Identification) systems and other sensors.

4.2 Antenna Specifications

4.2.1 Choice of Substrate

Choosing a substrate is as crucial as the design itself. The substrate itself is part of the antenna and contributes significantly to its radiative properties. Many different factors are considered in choosing a substrate such as dielectric constant, thickness, stiffness as well as loss tangent. The dielectric constant should be as low as possible to encourage fringing and hence radiation. A thicker substrate should also be chosen since it increases the impedance bandwidth. However, using a thick substrate would incur a loss in accuracy since most microstrip antenna models use a thin substrate approximation in the analysis. Substrates which are lossy at higher frequencies should not be used for obvious reasons. The choice of a stiff or soft board basically depends on the application. Hence we consider glass epoxy (FR4) as a substrate for designing the antenna. Its Dielectric Constant (ε_r) is 4.47.

4.2.1.1 **Height of Substrate (h):** The commonly used glass epoxy has height 1.56mm.

Hence essential parameters for designing RMSA are:

fr = 1.57GHz

ε_r = 4.47

h=1.56 mm

4.2.2 Element Length

To chose the resonant length would also mean choosing the frequency of resonance since the resonant frequency of the patch is determined by the patch length. The length of the patch should be slightly less than half the dielectric wavelength since the actual patch is 'longer' due to the fringing fields. The length of the patch is given as:

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{eff}}} \quad (4.1)$$

Where ε_{eff} :

$$\varepsilon_{eff} = \frac{(\varepsilon_r+1)}{2} + \frac{(\varepsilon_r-1)}{2}\left[1+\frac{12\,h}{W}\right]^{-\frac{1}{2}} \quad (4.2)$$

4.2.3 Element Width

For an efficient radiator, Bahl [10] recommended using a practical element width given by:

$$W = \frac{c}{2f_0\sqrt{\frac{\varepsilon_r+1}{2}}} \quad (4.3)$$

However, other widths may also be chosen especially if the widths are to be designed to radiate at a secondary frequency in dual-frequency operation. Square elements should be avoided in linearly polarized antennas to reduce the amount of cross polarization.

4.2.4 Input Impedance Matching

Impedance matching is critical in microstrip antennas since the bandwidth of the antenna depends upon it. Besides this, a poor match results in lower efficiency also Line fed rectangular patches may be fed from the radiating or the non-radiating edge.

To find an impedance match along the non-radiating edge we may use the Transmission Line Model. The input impedance along the non-radiating edge is lowest at the centre since two equally high impedances at the two ends are transformed into a low value at the centre and connected in parallel. Matching along the edge is also symmetrical about the mid-point of the length.

4.2.5 Calculations of finite plane dimensions (W_g and L_g)

The transmission line model is applicable to infinite ground planes only. However, for practical considerations, it is essential to have a finite ground plane. It has been shown by [15] that similar results for finite and infinite ground plane can be obtained if the size of the ground plane is greater than the patch dimensions by approximately six times the substrate thickness all around the periphery. Hence, for this design, the ground plane dimensions would be given as:

$$L_g = 6h + L$$
$$W_g = 6h + W$$

4.3 Simulation of a Patch Antenna at 2.4 GHz using IE3D

Design Specifications:-

- Resonance Frequency (fr) = 2.4GHz
- Dielectric Constant =4.47
- Height (h) = 1.56 mm
- Width (w) = 21 mm
- Length (l) = 30 mm

The Figure.4.1 shows the layout of Patch Antenna in IE3D software with Microstrip Line Feed with 50Ω.

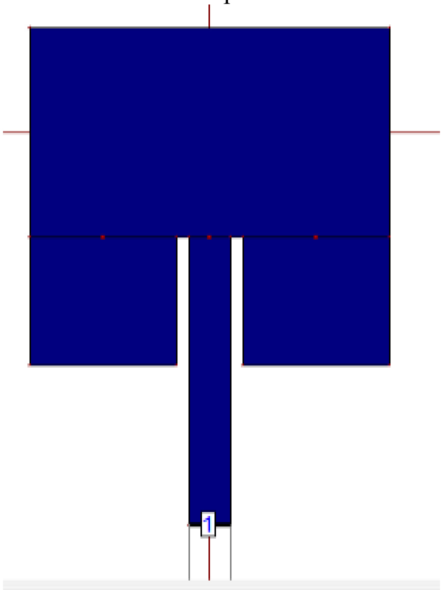

Figure.4.1 Antenna Layout

4.4 Simulation of a Patch Antenna Array at 2.4 GHz using IE3D

Design Specifications:-

- Resonance Frequency (fr) = 2.4GHz
- Dielectric Constant =4.47
- Height (h) = 1.56 mm
- Width (w) =38 mm
- Length (l) = 29mm

The Figure.4.2 shows the layout of Patch Antenna array with Corporate Microstrip Line Feed with 50Ω.

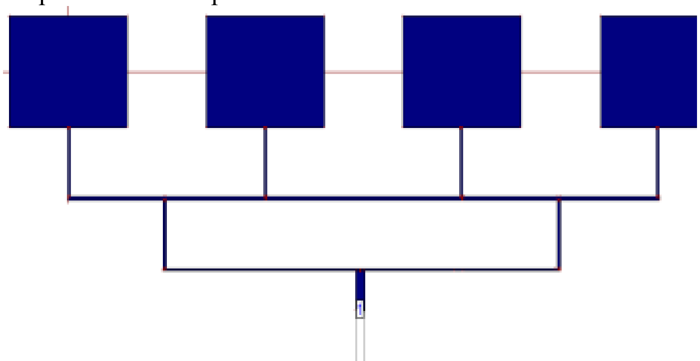

Figure.4.2 Antenna Array Layout in IE3D Software

V.RESULTS AND DISCUSSION

5.1 Directivity of Single Element Patch Antenna and Patch Antenna Array

It is a measure of how 'directional' an antenna's radiation pattern is. An antenna that radiates equally in all directions would have effectively zero directionality, and the directivity of this type of antenna would be 1 (or 0 dB).it is important to understand directivity in choosing the best antenna for your specific application. If you need to transmit or receive energy from a wide variety of directions (example: car radio, mobile phones, computer wifi), then you should design an antenna with a low directivity. Conversely, if you are doing remote sensing, or targeted power transfer (example: received signal from a mountain top), you want a high directivity antenna, to maximize power transfer and reduce signal from unwanted directions. Hence in this design Directivity of single patch from the Figure.5.13 is 7.4dBi and from the Figure.5.14 directivity for patch antenna array is 11.5dBi.

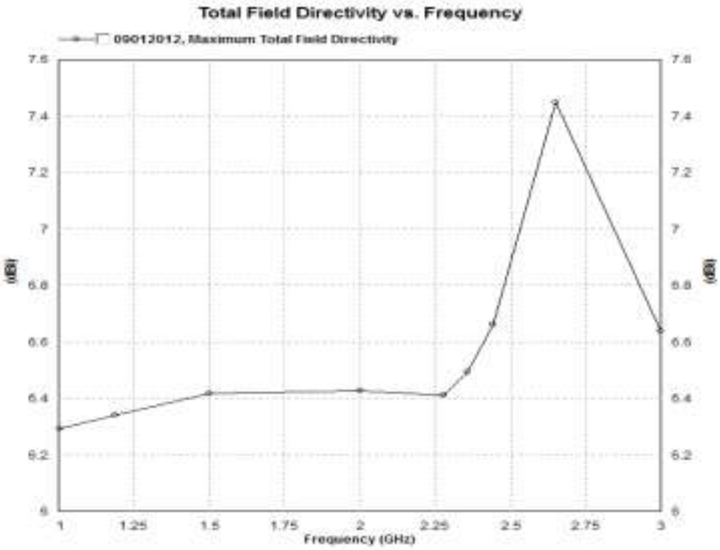

Figure.5.1 Directivity of Single Element Patch Antenna

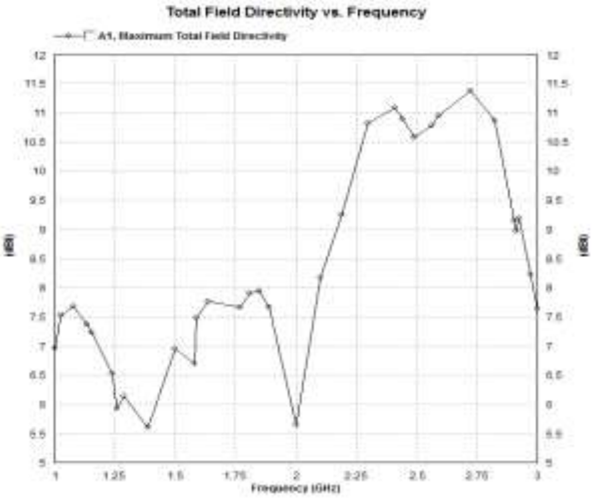

Figure.5.2 Directivity of Patch Antenna Array

5.2 Gain of Single Element Patch Antenna and Patch Antenna Array

The gain of a real antenna can be as high as 40-50 dB for very large dish antennas (although this is rare). Directivity can be as low as 1.76 dB for a real antenna (example: short dipole antenna), but can never theoretically be less than 0 dB. However, the peak gain of an antenna can be arbitrarily low because of losses or low efficiency. Electrically small antennas (small relative to the wavelength of the frequency that the antenna operates at) can be very inefficient, with antenna gains lower than -10 dB (even without accounting for impedance mismatch loss). The gain of a of a patch antenna and patch antenna array varies from 2dBi to 11dBi in this design gain for patch antenna from Figure.5.15 is 2.9dBi at 2.4GHz and from the Figure5.16 gain for patch antenna array is 9dBi at 2.4GHz.

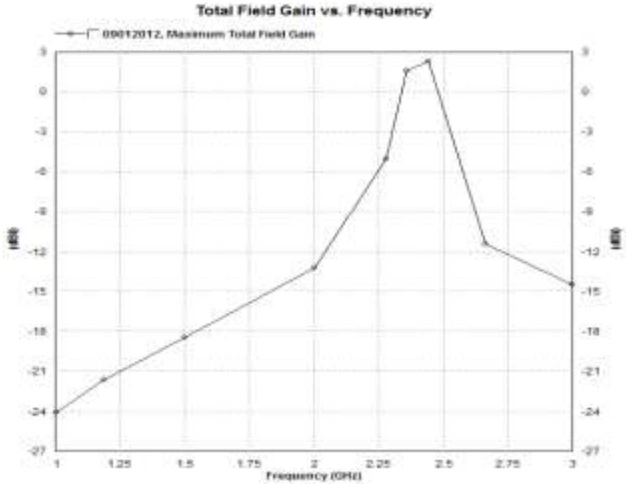

Figure.5.4 Gain of Single Element Patch Antenna

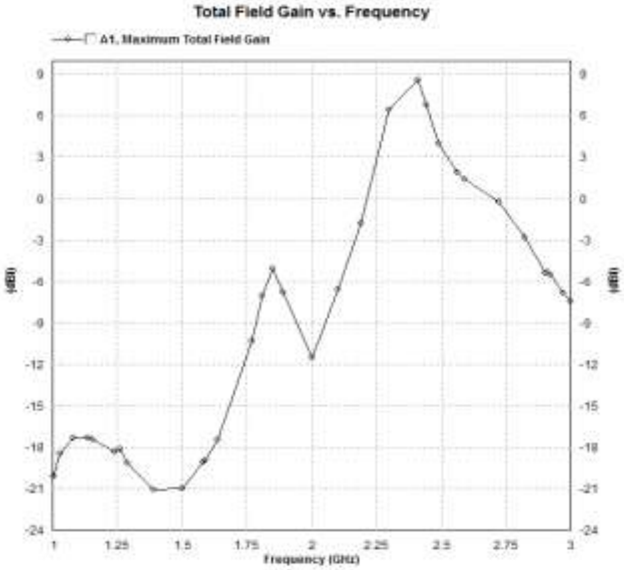

Figure.5.3 Gain of Patch Antenna Array

5.3 Antenna Efficiency of Single Element Patch Antenna and Patch Antenna Array

The efficiency of an antenna relates the power delivered to the antenna and the power radiated or dissipated within the antenna. A high efficiency antenna has most of the power present at the antenna's input radiated away. A low efficiency antenna has most of the power absorbed as losses within the antenna, or reflected away due to impedance mismatch. From the Figure.5.17 the Antenna Efficiency of Single Element Patch Antenna is 37% and from the Figure.5.18 the Antenna Efficiency of Patch Antenna array is 57%.

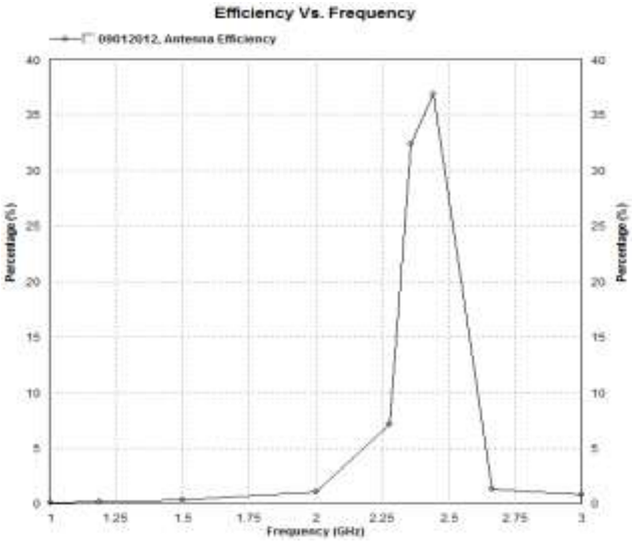

Figure.5.5 Antenna Efficiency of Single Element Patch Antenna

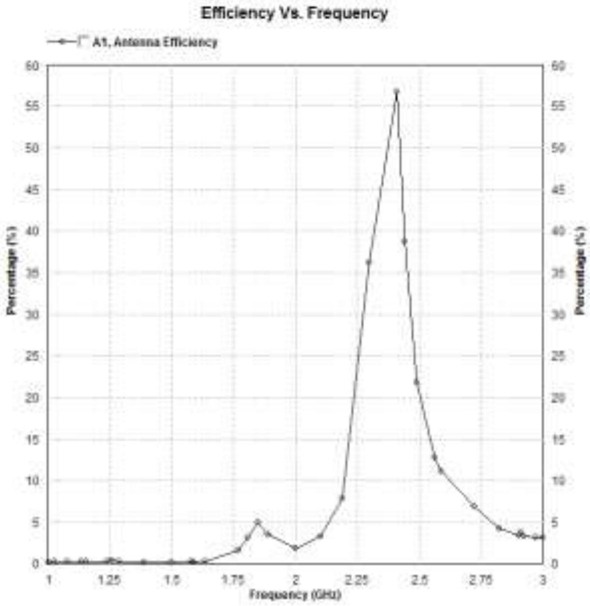

Figure.5.6 Antenna Efficiency of Patch Antenna Array

5.4 Radiation Efficiency of Single Element Patch Antenna and Patch Antenna Array

The Figure.19 and Figure.20 shows the Radiation Efficiency for Single Element Patch Antenna is 75% and for Radiation Efficiency of Patch Antenna Array is 75%.

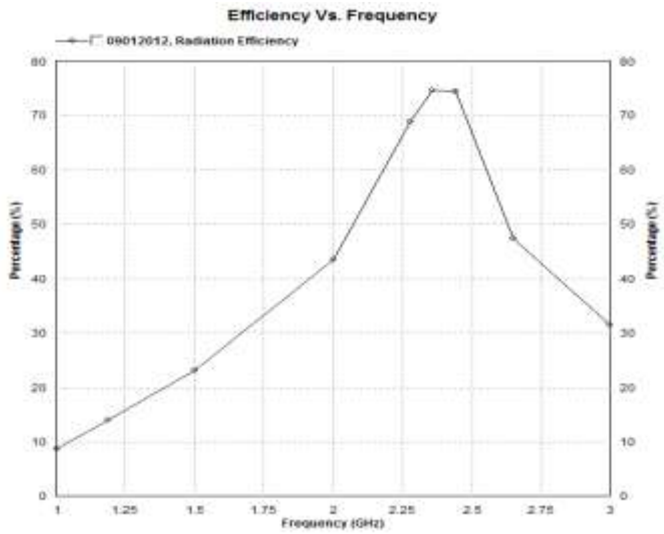

Figure.5.8 Radiation Efficiency of Single Element Patch Antenna

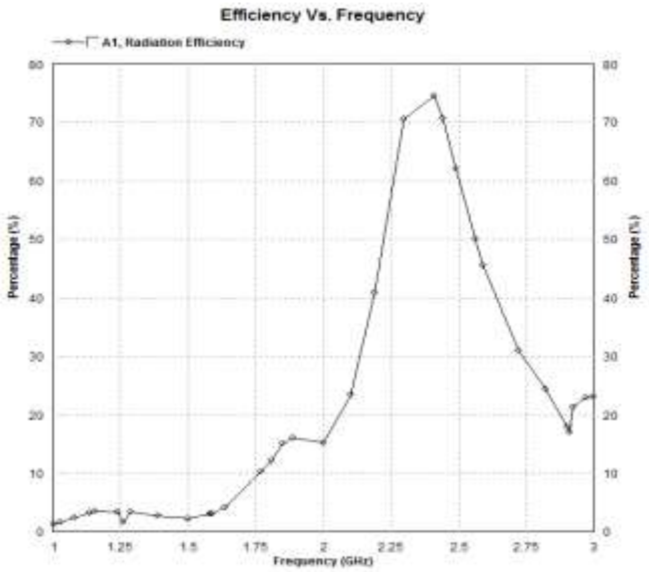

Figure.5.7 Radiation Efficiency of Patch Antenna Array

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