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Comparison of Lumped & Wave Port in Microstrip Antenna for Detecting Breast Tumor

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ABSTRACT

With the rapid increase in number of women suffering from breast cancer, it's early detection aids in fast and effective treatment. Mammography, which is currently the most popular method of breast screening, has some limitation and microwave imaging offers an attractive alteration. Microwave imaging is attractive due to high contrast in dielectric properties between cancerous and non-cancerous tissue. The paper presents different type of feeding mechanism to the micro strip patch antenna used in microwave imaging and its comparison in an urge of getting an ultra-wide band of 3GHz within the frequency range of 3.2 GHz to 10.6 GHz. The antenna is designed and simulated using Ansoft High Frequency Structure Simulator (HFSS).

Introduction

According to cancer incidence statics in 2012, 14.1 million people were diagnosed with cancer worldwide and 8,2 million people died from cancer [1]. Over about 100,000 new breast cancer patients are diagnosed per year in India. As per the ICMR-PBCR data, breast cancer is the most common cancer among women in urban registries of Mumbai, Ahmedabad, Calcutta and Trivandrum, where it constitutes of 30% of female's population suffering from cancer [2].

The causes of breast cancer disease remain unknown; however, significant progress has been accomplished for the treatment only if the cancer is detected in early stages. There are several methods of screening such as Mammography, Ultrasound, CT scan, MRI. Mammography is the gold standard method of breast imaging. The National Cancer Institute recommends women about 40-50 year of age to take mammography twice a year and beginning at age 50, screening should be performed every year [3].

Mammogram is two dimensional (2D) image of radiographic breast density, which helps in detecting tumor based on the differences in breast densities of tissues of the body [4]. This method is fraught with false negative rates ranging from 4% to 34% [4] apart from this ionizing nature of X-ray also poses a considerable risk of causing a very cancer which it attempts to detect. To provide a safer and more accurate method than Mammography, Microwave Breast Imaging techniques are developed. Microwave breast Imaging is based on the electrical property differences of breast tissues, namely the difference between healthy tissue and malignancies. The microwave frequency range extends from 300 MHz to 300 GHz, so microwave signal in free space have wavelength ranging from 1m to 1mm which are similar to dimensions of interest in human body.

The electrical or dielectric properties include relative permittivity (ε) and conductivity (σ). Water is a key factor in determining tissue permittivity [5]. Low water content tissues have high permittivity than high water content tissues [4]. At microwave frequencies, increased conductivity is associated with increased absorption or attenuation of microwave energy as it travels through material. The electrical properties of tumor tissues are 10% greater than that of healthy tissues [5].

There are three different approaches that have been proposed in order to provide microwave imaging of breast [6]: active, passive and hybrid. Passive microwave imaging for tumor detection is based on the assumption of an increased temperature compared to healthy breast tissue, which due to increase vascularization [6]. Hybrid microwave imaging exploit the advantages of microwave imaging and ultrasound. It uses microwaves to illuminate the breast, and ultrasound transducers to measure the signals for providing sensitivity to tumors and high resolution images [4]. Active imaging involves illuminating the breast with microwaves, detecting the energy reflected from or transmitted through the breast and forming images with these data. Active method is further classified as tomographic and radar-based. Microwave tomography is used to provide complete spatial mapping of the electrical properties. In this an array of antennas surrounds the region, out of this one antenna is used as transmitter and other antenna is used as receiver [7]. Radar-based imaging also called as confocal imaging [7]. Unlike tomographic imaging, it does not provide complete mapping of the breast, instead it identifies location of significant scattering. This method uses single antenna as transceiver that transmit ultra-wide band pulse, which propagate into the breast, where it is reflected off at electrical discontinuities and received by the same antenna.

In this paper radar based microwave imaging is proposed for detection of tumor at an early stage. This imaging system has advantages such as low cost, non- radiative and easy-use, high image resolution and thus with potential for early cancer detection. Signals used in radar-based approaches tend to have significant frequency content between 1 and 10 GHz. Usually

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employ short pulses, typically of the order of sub nanoseconds. These pulses have an extremely broad bandwidth, larger than 20% or 500 MHz [8] UWB signals may be transmitted between 3.1 GHz and 10.6 GHz at the effective isotropic radiated power (EIRP) levels up to -41dBm/MHz for the unlicensed use of commercial UWB system.

Antenna Layout and Structure

An ultra-wide microstrip patch antenna is designed using FR-4 Substrate with permittivity 4.2 and tangential loss of 0.008 Fig.1 shows the proposed antenna consist of a wide rectangular slot with one side of substrate and on other side of substrate forked microstrip feed is used.

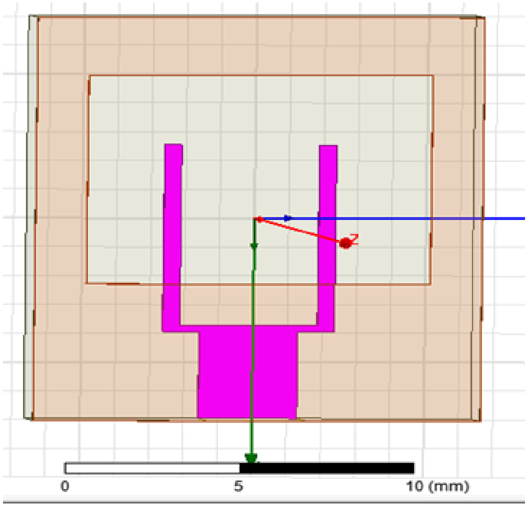

Figure 1. Wide Slot Antenna with Forked Feed

Forked feed is used to increase the bandwidth. The forked tuning stub is all positioned within slot region on the other side of wide slot to control coupling between the microstrip line and wide rectangular slot more effectively. To obtain the results 50Ω microstrip feed line is designed with the formulas given below to obtain width of feed line.

$$w/d=\begin{Bmatrix} 8e^{A}/e^{2A}-2;\ for\ w/d>2 \\ 2/\pi[B-1-\ln(2B-1)+\varepsilon_r-1/2\varepsilon_r\{\ln(B-1)+0.39-(0.61/\varepsilon_r)\}];\ for\ w/d<2 \end{Bmatrix} \quad (1)$$

Where,

$$A= Z_0(\varepsilon_r+1)^{1/2}/120+(\varepsilon_r-1)/(\varepsilon_r+1)[0.23+0.11/\varepsilon_r]$$

$$B= 377\pi/2Z_0\varepsilon_r^{1/2}$$

Table1 give the brief summary of all parameter used for designing of this wide slot antenna.

Table I . Designed Antenna Parameter

Parameters	Value
Substrate Material	FR 4
Substrate Thickness	1.6mm
Antenna Length	13mm
Antenna Width	14mm
Slot Length	10mm
Slot Width	7.25mm
Microstrip Width	2.87mm

This antenna is designed using Ansoft HFSS with input port as wave port and lumped port as shown in fig 2 and fig 3 to support uniform field distribution.

In HFSS wave port is created only on external boundary as shown in above fig.2 and mode pattern are used for the excitation of antenna. Wave port supports multiple modes and de-embedding; it solves actual field distributions for one or more propagating or non-propagating Modes. A two-dimensional eigenvalue problem is solved first to find the Wave guide modes of this port, then generalized S-parameters are computed by matching the fields on the port to the mode pattern. Integration line is used at wave port to align the right mode patterns to make S parameter computation consistent. An integration line is also used to compute Characteristic impedances.

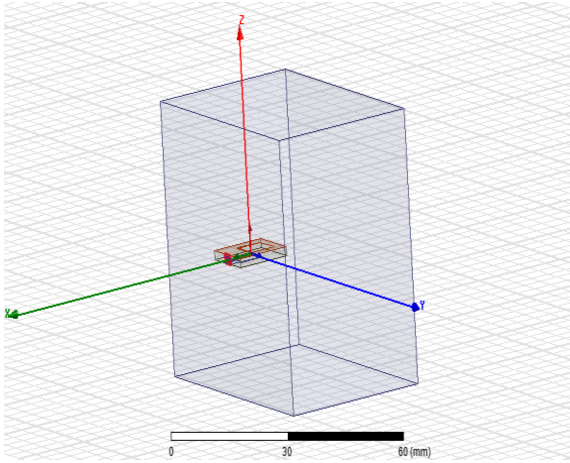

Figure 1. Microstrip Feed with Wave Port (Antenna I)

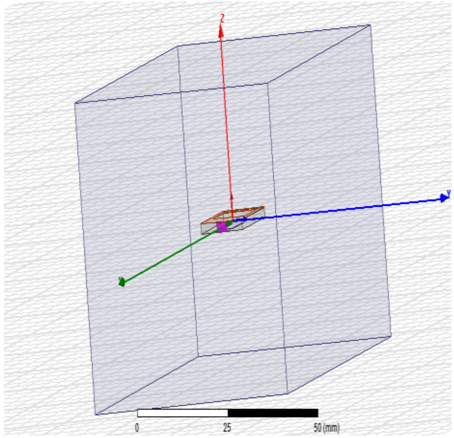

Figure 2. Microstrip Feed with Lumped Port (Antenna II)

In HFSS lumped port is recommended only for surfaces internal to geometric model as shown in above fig. 3. Unlike wave port, lumped port support single mode and no-de-embedding. An integration line is used to indicate path of electric filed. For lumped port perfect E or finite conductivity boundary conditions are used for port edges which interface with conductor and perfect H for all remaining port edges. Complexity to setup lumped port is low as compare to wave port.

Results

HFSS software based on finite element method (FEM) is used for calculating return loss, impedance, gain, directivity and VSWR for both the antenna i.e. wave port and lumped port. For wave port antenna the resonant frequency is obtain at 4.8GHz. The maximum achievable gain at the frequency of 4.8GHz is -1. 2851dB.For lumped port antenna the resonant frequency is obtained at 6.3GHz. The maximum achievable gain at the frequency of 6.3GHz is 4.0087dB. It is observed that antenna exhibits ultra-wide bandwidth of 3.2 GHz & 3GHz with both wave port and lumped port antenna & and shows VSWR is less than 2 for complete bandwidth.

I. Return Loss

The s parameter gives return loss of microstrip antenna. The return loss is a parameter which indicates how much power is reflected back from the antenna. This is also called as reflection coefficient of antenna.

The fig.4 and fig.5 shows return loss v/s frequency graph for wave port and lumped port antenna.

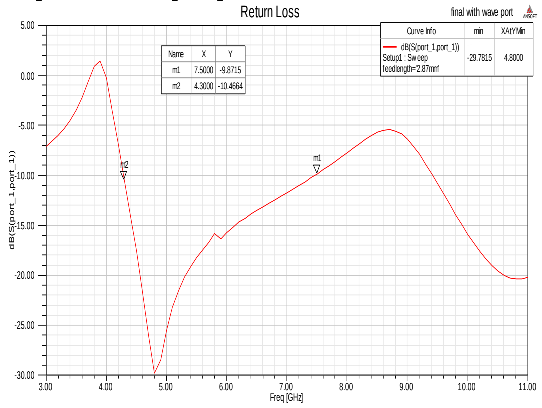

Figure 4. Graph of Return Loss v/s Frequency of wave port (Antenna I)

Return Loss at 4.8GHz = -29.7851dB

Frequency range for acceptable return loss (-10dB) = 4.3Ghz-7.5Ghz

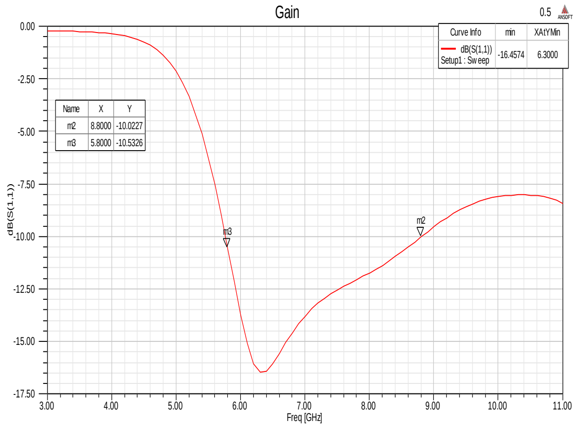

Figure 5. Graph of Return Loss v/s Frequency of lumped port (Antenna II)

Return Loss at 6.3GHz = -16.4574dB

Frequency range for acceptable return loss (-10dB) = 5.8Ghz-8.8Ghz.

II. Voltage Standing Wave Ratio (VSWR)

VSWR is the function of reflection coefficient of antenna, which describes power reflected from antenna. VSWR is a measures that numerically describe how well the antenna is impedance matched to connected transmission line. The bandwidth of antenna is defined by acceptable value of VSWR (1 ≤ VSWR ≤ 2) over concerned frequency range. The fig.6 & fig. 7 shows VSWR v/s frequency graph of both the antennas.

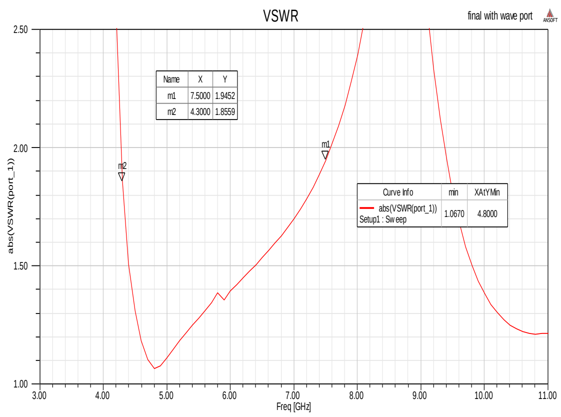

Figure 6. Graph of VSWR v/s Frequency of Wave Port (Antenna I)

VSWR at 4.8 GHZ = 1.0670

VSWR ≤ 2 for = 4.3 GHz- 7.5 GHz

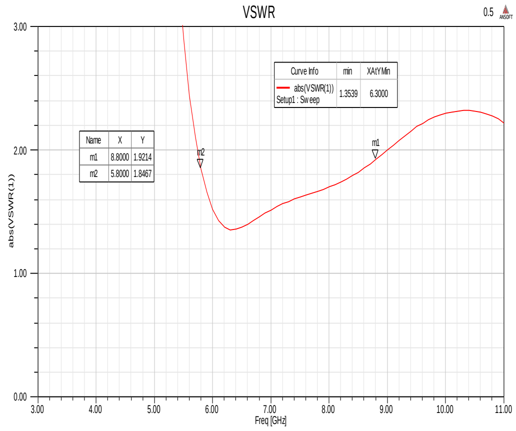

Figure 7. Graph of VSWR v/s Frequency of Lumped Port (Antenna II)

VSWR at 6.3 GHZ = 1.3539

VSWR ≤ 2 for = 5.8 GHz- 8.8 GHz

III. Gain and Directivity

Antenna gain is parameter closely related to directivity of antenna. Directivity is how much antenna radiates in one direction in preference to other direction. The fig.8 & fig.9 shows gain v/s elevation angle graph at 4.8 GHz and at 6.3 GHz frequency. The fig.10 and fig.11 shows directivity v/s elevation angle graph at 4.8 GHz and at 6.3 GHz frequency.

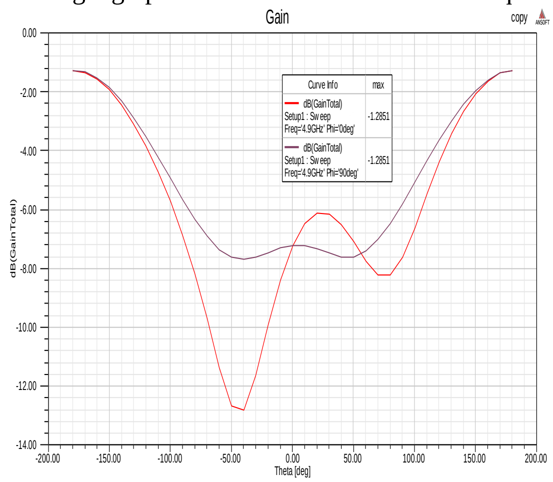

Figure 8. Graph of Gain for Wave Port (Antenna I)

Maximum gain at 4.8 GHz = -1.2851dB

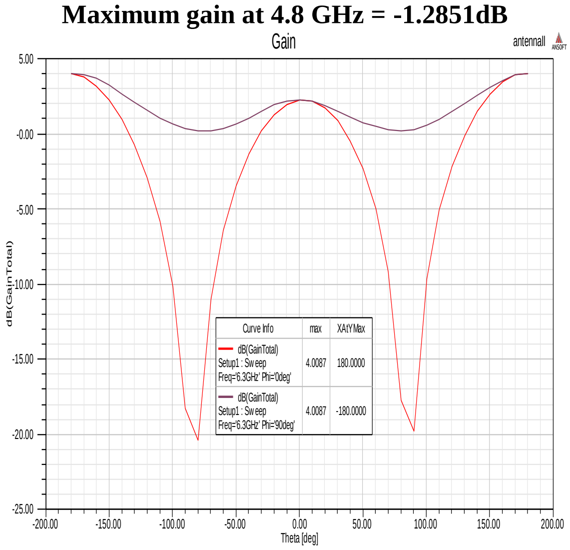

Figure 9. Graph of Gain for Lumped Port (Antenna II)

Maximum gain at 6.3 GHz = 4.0087dB

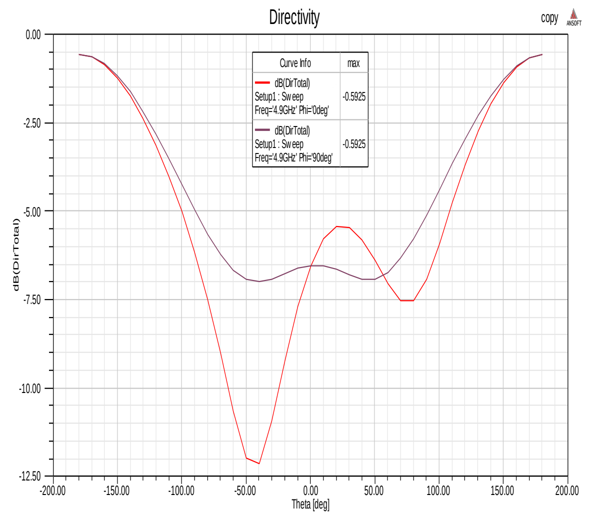

Figure 10. Graph of Directivity for Wave Port (Antenna I)

Maximum directivity at 4.8 GHz = -0.5929dB

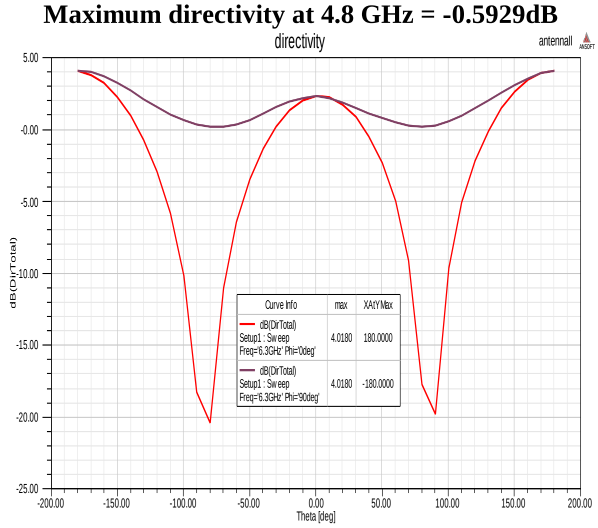

Figure 11. Graph of Directivity for Lumped Port (Antenna II)

Maximum directivity at 6.3 GHz = 4.0180dB

IV. Radiation Pattern

Radiation pattern represent energy transmitted in free space. The fig.12 to fig.15 shows 2D radiation pattern for both antennas in azimuth plane and elevation plane.

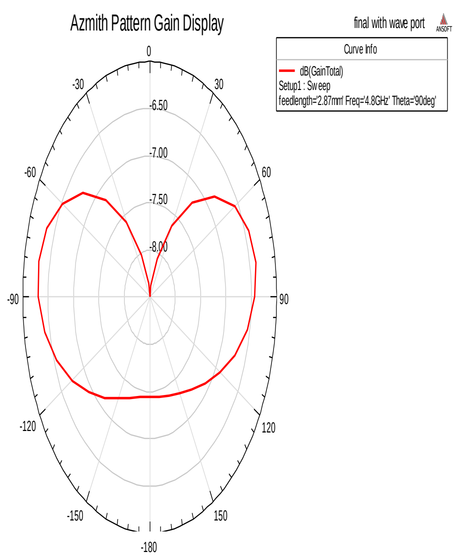

Figure 12. 2D Radiation Pattern of Wave Port (Antenna I) in Azimuth Plane

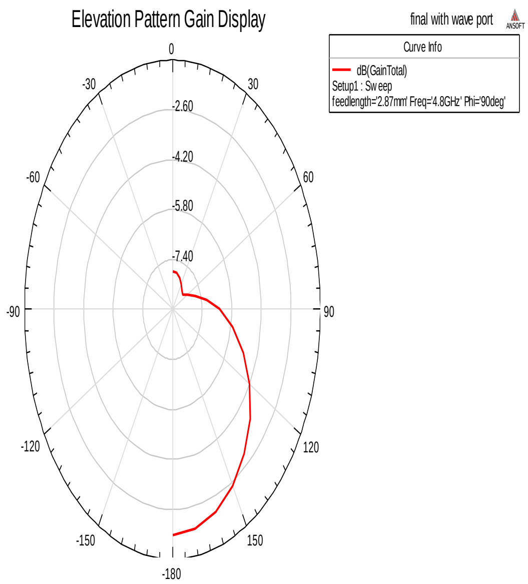

Figure 13. 2D Radiation Pattern of Wave Port (Antenna I) in Elevation Plane

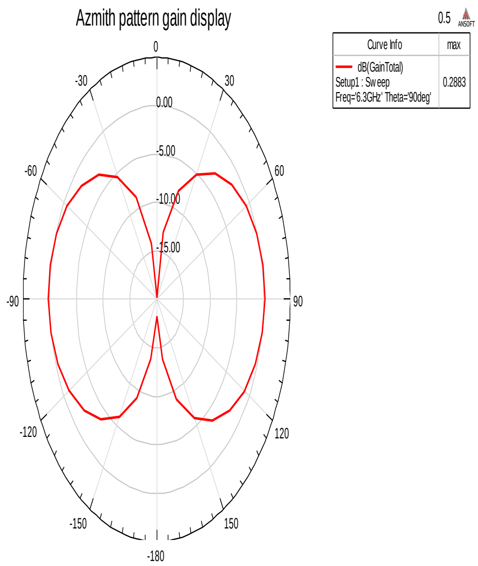

Figure 14. 2D Radiation Pattern of Lumped Port (Antenna II) in Azimuth Plane

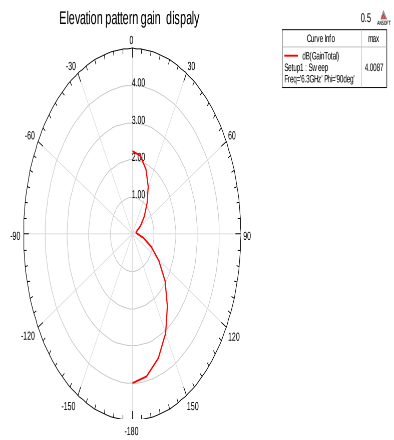

Figure 15. 2D radiation pattern of Lumped Port (Antenna II) in Elevation Plane

V. 3D Polar Plot

Polar Plot represent 3D radiation pattern of antenna. The fig. 16 & fig. 17 shows polar plot of gain of antenna at frequency 4.8 GHz & 6.3 GHz.

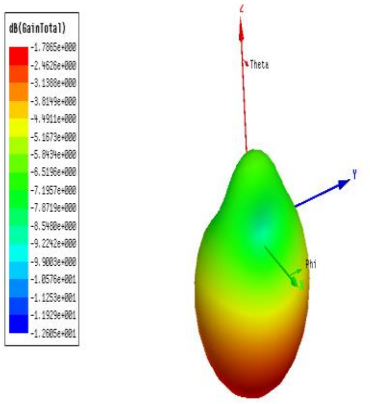

Figure 16. Polar Plot of Gain for Wave Port (Antenna I)

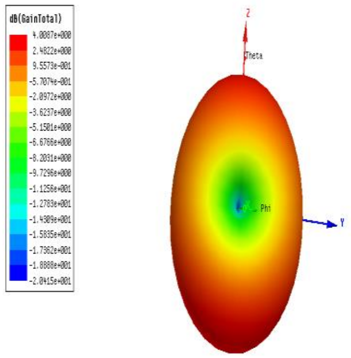

Figure 17. Polar plot of gain for Lumped Port (Antenna I)

Table 2 give comparison of both wave port (Antenna I) and Lumped port (Antenna II) on basis of different results obtained.

Table II. Comparison of Antenna I & Antenna II

Parameters	Antenna I	Antenna II
Bandwidth	3.2 GHz	3 GHz
Return Loss	-29.7815dB	-16.4574dB
VSWR	1.0670 at 4.8 GHz	1.3539 at 6.3 GHz
Gain	-1.2851dB	4.0087dB
Directivity	-0.5925dB	4.0180dB

VI. Conclusion

A wide slot ultra-wide band microstrip antenna using wave port and lumped port is designed for radar based microwave imaging has been presented. As seen from the results both the antennas yield ultra-wide bandwidth of 3 GHz and 3.2 GHz which is greater than 0.2 times of central frequency. VSWR of 1.0670 & 1.3539 which is less than 2 for entire range of bandwidth. While considering return loss and VSWR wave port would be a better option but Maximum directivity and gain is obtained using lumped port. Thus for microwave imaging lumped port antenna would be a better option for obtaining satisfactory results which could be used for detection of breast tumor.

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