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Multibanding of microstrip patch antenna by double J - slot method

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***Abstract*— This paper investigate some methods for converting single band antennas to multiband antennas so that all single band antennas convert in multiband antennas and gives multiband facility without increasing the cost of manufacturing. Simulation is performing on Ansoft HFSS and corresponding result are shown by figures.Impedance bandwidth, antenna gain and return loss are observed for the proposed antenna. This proposed patch antenna is suitable for implementing low cost and high stable pattern. Details of the measured and simulated results are presented and discussed.**

***Index Terms*—Microstrip Antenna, Resonant Frequency, Radiation Pattern, Return Losses.**

I. INTRODUCTION

In high performance aircraft, spacecraft, satellite, and missile applications where size, weight, cost, performance, ease of installation, low profile, easy integration to circuits, high efficiency antennas may be required. Presently there are many other government and commercial applications, such as mobile radio and wireless communication.[1]To meet these requirements microstrip antenna can be used. There are several types of microstrip antennas (also known as printed antennas) the most common of which is the microstrip patch antenna or patch antenna. A patch antenna is a narrowband, wide-beam antenna These antennas are low profile, conformal to planar and non-planar surface, simple and inexpensive to manufacture using modern printed circuit technology, mechanically robust when mounted on rigid surface, compatible with MMIC designs and when the particular shape and mode are selected they are very versatile in terms of resonant frequency, polarization, field pattern and impedance. Microstrip antenna consist of a very thin metallic strip (patch) placed a small fraction of a wavelength above a ground plane. 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. The patch and ground plane are separated by dielectric material. Patch and ground both are fabricated by using conducting material.[2]

However the major disadvantage of the microstrip patch antenna is its inherently narrow impedance bandwidth. Much intensive research has been done in recent years to develop bandwidth enhancement techniques.[9] The most desirable for good antenna performance are thick substrates whose dielectric constant is in the lower end of the range because they provide better efficiency, larger bandwidth, loosely bound fields for radiation into space, but at the expense of larger element size. These techniques includes the utilization of thick substrates with low dialectic constant .The use of electronically thick substrate only result in limited success because a large inductance is introduce by the increased length of the probe feed, resulting few percentage of bandwidth at resonant frequency.

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A. *Basic principles of operation*

The metallic patch essentially creates a resonant cavity, where the patch is the top of the cavity, the ground plane is the bottom of the cavity, and the edges of the patch form the sides of the cavity. The edges of the patch act approximately as an open-circuit boundary condition. Hence, the patch acts approximately as a cavity with perfect electric conductor on the top and bottom surfaces, and a perfect “magnetic conductor” on the sides. This point of view is very useful in analyzing the patch antenna, as well as in understanding its behavior. Inside the patch cavity the electric field is essentially *z* directed and independent of the z coordinate. Hence, the patch cavity modes are described by a double index (*m*, *n*). For the (*m*, *n*) cavity mode of the square patch the electric field has the form

$$E_z(x,y) = A_{mn}\cos\left(\frac{m\pi x}{L}\right)\cos\left(\frac{n\pi y}{W}\right)$$

Where *L* is the patch length and *W* is the patch width. The patch is usually operated in the (1, 0) mode, so that *L* is the resonant dimension, and the field is essentially constant in the *y* direction. The surface current on the bottom of the metal patch is then x directed, and is given by

$$J_{sx}(x) = A_{10}\left(\frac{\pi / L}{j\omega\mu_0\mu_r}\right)$$

For this mode the patch may be regarded as a wide microstrip line of width *W*, having a resonant length *L* that is approximately one-half wavelength in the dielectric. The current is maximum at the centre of the patch, *x* = *L*/2, while the electric field is maximum at the two “radiating” edges, *x* = 0 and *x* = *L*. The width *W* is usually chosen to be larger than the length (*W* =1.5 *L* is typical) to maximize the bandwidth, since the bandwidth is proportional to the width. (The width should be kept less than twice the length, however, to avoid excitation of the (0,2) mode). Here we are using square type microstrip patch antenna, so we have equal length and width of patch antenna. At first glance, it might appear that the microstrip antenna will not be an effective radiator when the substrate is electrically thin, since the patch current will be effectively shorted by the close proximity to the ground plane. If the modal amplitude $A10$ were constant, the strength of the radiated field would in fact be proportional to h. However, the Q of the cavity increases as h decreases (the radiation Q is inversely proportional to h). Hence, the amplitude $A10$ of the modal field at resonance is inversely proportional to h. Hence, the strength of the radiated field from a resonant patch is essentially independent of h, if losses are ignored. The resonant input resistance will likewise be nearly independent of h. This explains why a patch antenna can be an effective radiator even for very thin substrates, although the bandwidth will be small.

B. *Resonant frequency*

The resonance frequency for the (1, 0) mode is given by

$$f_0 = \frac{c}{2L_e\sqrt{\varepsilon_r}}$$

Where c is the speed of light in vacuum. To account for the fringing of the cavity fields at the edges of the patch, the length, the effective length Le is chosen as

$$Le = L + 2\Delta L$$

The Hammers tad formula for the fringing extension is

$$\frac{\Delta L}{h} = 0.412\left(\frac{(\varepsilon_{eff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{eff}-0.258)\left(\frac{W}{h}+0.8\right)}\right)$$

Where

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left(1+\frac{12h}{W}\right)^{-1/2}$$

C. *Radiation Efficiency*

The radiation efficiency of the patch antenna is affected not only by conductor and dielectric losses, but also by surface-wave excitation - since the dominant TM0 mode of the grounded substrate will be excited by the patch. As the substrate thickness decreases, the effect of the conductor and dielectric losses becomes more severe, limiting the efficiency. On the other hand, as the substrate thickness increases, the surface-wave power increases, thus limiting the efficiency. Surface-wave excitation is undesirable for other reasons as well, since surface waves contribute to mutual coupling between elements in an array, and also cause undesirable edge diffraction at the edges of the ground plane or substrate, which often contributes to distortions in the pattern and to back radiation. For an air (or foam) substrate there is no surface-wave excitation. In this case, higher efficiency is obtained by making the substrate thicker, to minimize conductor and dielectric losses. For a substrate with a moderate relative permittivity such as $\varepsilon_r = 4.4$, the efficiency will be maximum when the substrate thickness is approximately $\lambda 0 = 1.524$mm. The radiation efficiency is defined as

$$e_r = \frac{P_{sp}}{P_{total}} = \frac{P_{sp}}{P_c + P_d + P_{sw} + P_{sp}}$$

Where P_{sp} is the power radiated into space, and the total input power $P\ total$ is given as the sum of Pc the power dissipated by conductor loss, P_d the power dissipated by dielectric loss, and P_{SW} the surface-wave power. The efficiency may also be expressed in terms of the corresponding Q factors as

$$e_r = (Q_{sp}/Q_{total})^{-1}$$

Where

$$\frac{1}{Q_{total}} = \frac{1}{Q_c} + \frac{1}{Q_d} + \frac{1}{Q_{sw}} + \frac{1}{Q_{sp}}$$

The dielectric and conductor Q factors are given by

$$Q_d = \frac{1}{\tan\delta_d}$$

$$Q_c = \frac{1}{2}\mu_r\eta_0\left(\frac{k_0}{R_s}h\right)$$

Where $\tan\delta_d$ is the loss tangent of the substrate and Rs is the surface resistance of the patch and ground plane metal at radian frequency $\omega = 2\pi f$, given by

$$R_s = \left(\frac{\omega\mu_0}{2\sigma}\right)^{\frac{1}{2}}$$

where σ is the conductivity of the metal.

D. *Bandwidth*

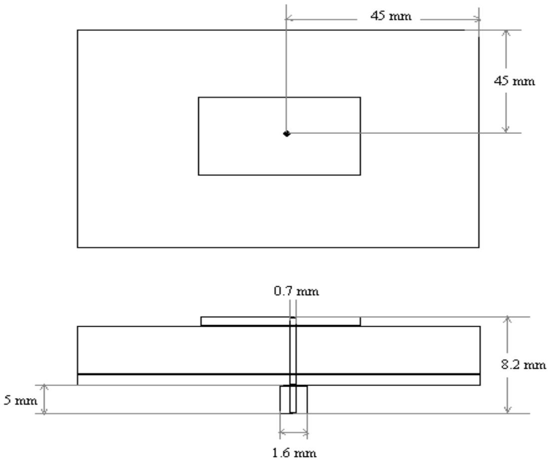
The bandwidth increases as the substrate thickness increases (the bandwidth is directly proportional to h if conductor, dielectric, and surface-wave losses are ignored). However, increasing the substrate thickness lowers the Q of the cavity, which increases spurious radiation from the feed, as well as from higher-order modes in the patch cavity. Also, the patch typically becomes difficult to match as the substrate thickness increases beyond a certain point (typically about 0.05 $\lambda 0$). This is especially true when feeding with a coaxial probe, since a thicker substrate results in a larger probe inductance appearing in series with the patch impedance. However, in recent years considerable effort has been spent to improve the bandwidth of the microstrip antenna, in part by using alternative feeding schemes. The aperture-coupled feed is one scheme that overcomes the problem of probe inductance, at the cost of increased complexity .

Lowering the substrate permittivity also increases the bandwidth of the patch antenna. However, this has the disadvantage of making the patch larger. Also, because the of the patch cavity is lowered, there will usually be increased radiation from higher-order modes, degrading the polarization purity of the radiation.

By using a combination of aperture-coupled feeding and a low-permittivity foam substrate, bandwidths exceeding 25% have been obtained. The use of stacked patches (a parasitic patch located above the primary driven patch) can also be used to increase bandwidth even further, by increasing the effective height of the structure and by creating a double-tuned resonance effect.

II. ANTENNA DESIGN

The single band rectangular microstrip antenna is shows in figure 2.1. In this the dielectric substrate has two surfaces these surfaces are fully metalized. First surface is known as ground plane and the second surface is known as patch. Copper is used as a coaxial feed. The thickness, height and position of feeding is shown in figure 2.1.



Figur2.1: Feeding position (Antenna A)

The antenna A is a single band antenna. The feed point of patch antenna is at center (45, 45). If we create a double J slot in the patch then this antenna works on triple Band. This antenna is known as Antenna "J". JJ slot is the combination of six slots $L_1, L_2, L_3, L_4, L_5, L_6$. In First J Slot L_1 is half wavelength long. Slots L_1, L_3 are parallel to each other. Slot L_2 is connected vertically to these two slots L_1, L_3. So a J shape is created by connecting these three slots. In Second J Slot Slots L_4, L_6 are parallel to each other. Slot L_5 is connected vertically to these two slots L_4, L_6. So a second J shape is created by connecting these three slots. By changing the length of these slots we can change resonant frequency and can convert single band antenna to a multiband antenna..This antenna is known as Antenna "B" shown in figure 2.2.

The coaxial feed is used for feeding. The thickness, height and position of feeding are shown in figure 2.2.

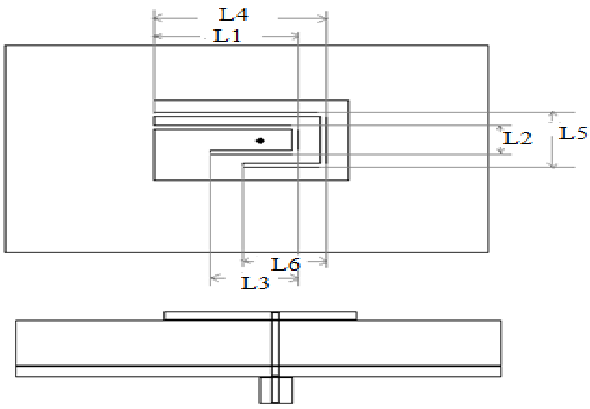


Figure 2.2: Feeding position (Antenna B)

III. RESULTS AND DISCUSSION

The simulation is done on Ansoft HFSS. Single band microstrip patch antenna simulation model of antenna A is shown in figure 3.1. The coaxial feed used in designed to have a radius of 0.7 mm. The center frequency is selected as the one at which the return loss is minimum.

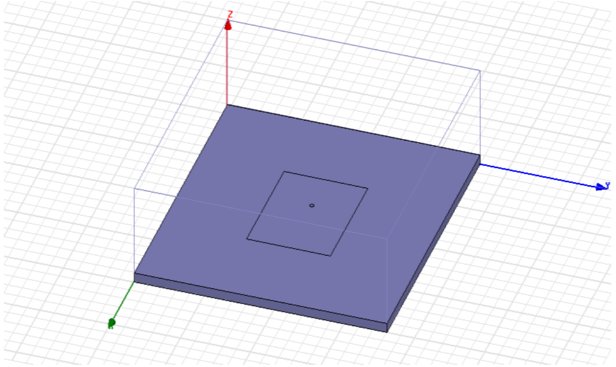


figure 3.1. simulation model(Antenna A)

Return loss and antenna bandwidth:

The bandwidth of this patch antenna is 50 MHz and a center frequency 2360 MHz is obtained. Figure 3.2 shows the Return loss (in dB) is plotted as a function frequency.

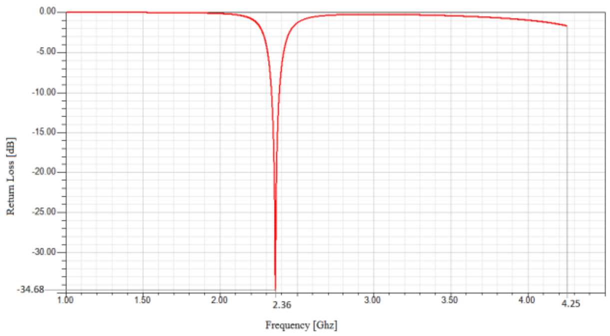


Figure 3.2: Return loss of patch antenna (Antenna A)

VSWR:

Voltage standing wave ratio (VSWR) is an important property of patch antenna. Figure 3.3 shows the VSWR (in dB) is plotted as a function frequency. The VSWR of this antenna at center frequency is 0.33 dB.

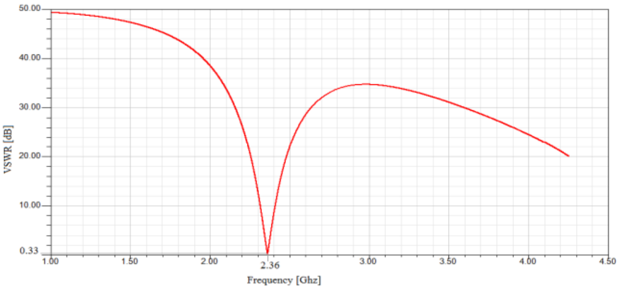


Figure 3.3: VSWR of Patch antenna (Antenna A)

simulation model of antenna B is shown in figure 3.4.

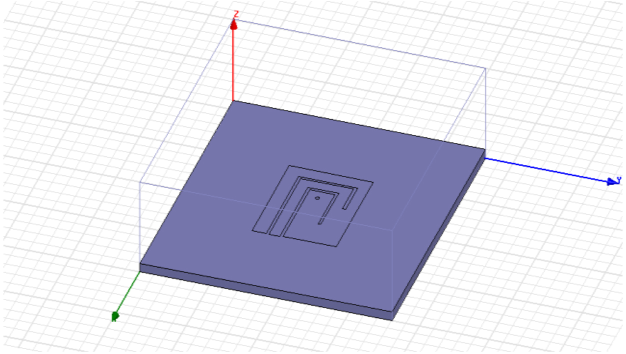


Figure 3.4: Simulation model of patch antenna (Antenna B)

Return loss and antenna bandwidth:

The bandwidth of First Band of this patch antenna is 22 MHz and a center frequency 1988 MHz, bandwidth of Second Band of this patch antenna is 49 MHz and a center frequency 3111 MHz and bandwidth of Third Band of this patch antenna is 74 MHz and a center frequency 4099 MHz are obtained Figure 3.5 shows the Return loss (in dB) is plotted as a function frequency.

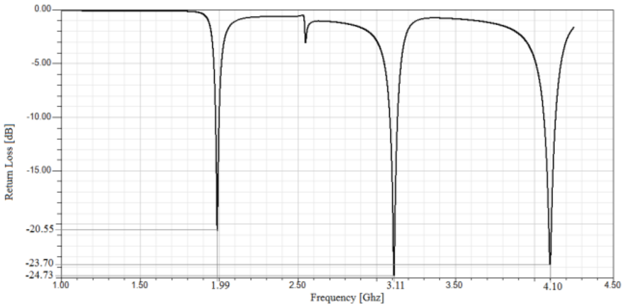


Figure 3.5: Return Loss of patch Antenna (Antenna A)

VSWR:

Voltage standing wave ratio (VSWR) is an important property of patch antenna. Figure 7.22 shows the VSWR (in dB) is plotted as a function frequency. The VSWR of first band at center frequency is 1.67 dB, VSWR of second band at center frequency is 1.01 dB and VSWR of Third band at center frequency is 1.20 dB.

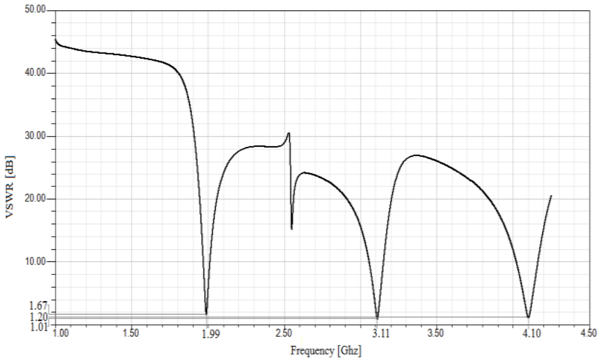


Figure 3.6: VSWR of Patch Antenna (Antenna B)

IV. CONCLUSIONS

For antenna A bandwidth of patch antenna is 50 MHz and a center frequency 2360 MHz is obtained.The VSWR of this antenna at center frequency is 0.33 dB.For antenna B after making double slot bandwidth of First Band of this patch antenna is 22 MHz and a center frequency 1988 MHz, bandwidth of Second Band of this patch antenna is 49 MHz and a center frequency 3111 MHz and bandwidth of Third Band of this patch antenna is 74 MHz and a center frequency 4099 MHz are obtained

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