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Microstrip Patch Antennas for Broadband Indoor Wireless Systems

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Abstract— The advantages of microstrip antennas have made them a perfect candidate for use in the wireless local area network (WLAN) applications. Though bound by certain disadvantages, microstrip patch antennas can be tailored so they can be used in the new high-speed broadband WLAN systems. This paper concentrates on manufacture of broadband microstrip patch antennas for the 2.45 GHz ISM band and possible implementation using adhesive copper tape in research scenarios. In this paper, two broadband microstrip patch antennas were manufactured to adequately cover the 2.4- 2.5 GHz frequency band. A test procedure was also devised to compare the area coverage mappings, in term of path loss, of the in-house built antennas to the commercial broadband antennas. The testing show, the in-house antennas demonstrate larger bandwidth response compared to the commercial product but commercial product has a larger beam width and illustrate a better coverage. The presented paper is used to design efficient and reliable broadband patch antennas showing signs of directivity leading to adequate area coverage and sufficient bandwidth usage.

Keywords— Microstrip Patch Antenna, Frequency Band, WLAN, VSWR, Bandwidth.

I. Introduction

Currently there is a boom in the development of personal communication service (PCS) devices as they are now deeply integrated into society. The PCS arena covers everything from cellular phones that incorporate digital cameras and web browsing to Wireless Local Area Networks (WLAN). Since they can all be linked together, their applications are no longer limited. It is now both possible and affordable to surf the web from our Laptop without any wire connectivity, while enjoying the rugby match on your television.

A WLAN is a flexible data communication network used as an extension to, or an alternative for, a wired LAN in a building. The increasing popularity of indoor wireless LAN capable of high-speed transfer rate is prompting the development of efficient broadband antennas. Due to increased usage in residential and office areas, these systems are required to be low profile, aesthetically pleasing and low cost as well as highly effective and efficient. Microstrip patch antennas are well suited for wireless LAN application systems due to their versatility, conformability, low cost and low sensitivity to manufacturing tolerances. Conventionally patch antennas have showed a narrowband response, implicating low bit rate transfer. Recently importance has been placed upon creating patch antennas that show broadband properties, capable of high-speed data transfer.

ANTENNAS FOR WIRELESS LAN SYSTEMS

Currently the most commonly used WLAN system is the IEEE 802.11b system, with a maximum throughput of 11 Mbps using a narrowband system. Keeping on par with the growth of broadband connectivity in the landline sector, the new generation of WLAN systems are designed with a maximum throughput of at least 54 Mbps. Broadband refers to transmission of information using a system that uses a comparatively larger frequency band, resulting in increases

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data transfer rate or throughput. If the broadband WLAN is to make an entry into the market and have an impact, it is important that the systems are versatile and performs extremely well. The broadband 802.11a system requires them to have a good coverage without failing signal strength. The range of coverage is dependent directly on the antenna performance hence the significance of the broadband antenna. A key requirement of a WLAN system is that it should be low profile, where it is almost invisible to the user. For this reason the microstrip patch antennas are the antennas of choice for WLAN use due to their small real estate area and the ability to be designed to blend into the surroundings. The system coverage often needs to be limited to designated areas, and since the 802.11x systems use the ISM bands, there are transmitted power limitations to reduce interference. It is important for the system to be highly directive in order to reduce coverage in unwanted areas. Primarily, it is due to possible LAN security breaches in case the LAN's coverage extends outside the property and received by unwanted parties.

II. FOUNDATIONS FOR MICROSTRIP DESIGN

A microstrip patch antenna is a radiating patch on one side of a dielectric substrate, which has a ground plane. The EM waves fringe off the top patch in to the substrate, reflecting off the ground plane and radiates out into the air. Radiation occurs mostly due to the fringing field between the patch and ground.

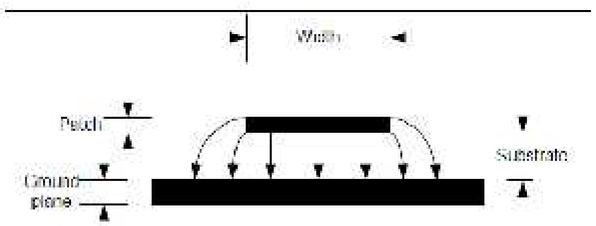

Fig. 1 Linear Polarization

The radiation efficiency of the patch antenna depends largely on the permittivity (Ɛr) of the dielectric. Ideally, a thick dielectric, low Ɛrand low insertion loss is preferred for broadband purposes and increased efficiency. The advantages of microstrip antennas are that they are low-cost, conformable, lightweight and low profile, while both linear and circular polarization is easily achieved. These attributes are desirable when considering antennas for WLAN systems.

A. Polarization Types

This is the polarization of the wave radiated by the antenna in that particular direction. This is usually dependant on the feeding technique. When the direction is not specified, it is in the direction of maximum radiation [1]. Shown below are two most widely used polarization types.

1. Linear Polarization

A slot antenna is the counterpart and the simplest form of a linearly polarized antenna. On a slot antenna the E field is orientated perpendicular to its length dimension. The usual microstrip patches are just different variations of the slot antenna and all radiate due to linear polarization. Fig-2 illustrates the operations of a linearly polarized wave radiating perpendicular to the patch plane.

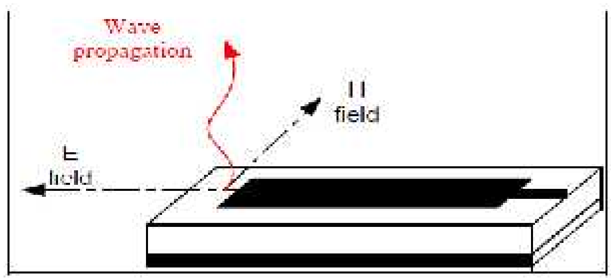

Fig. 2 Linear Polarization

2. Circular Polarization

Circular polarization (CP) is usually a result of orthogonally fed signal input. When two signals of equal amplitude but 90o phase shifted the resulting wave is circularly polarized. Circular polarization can result in Left hand circularly polarized (LHCP) where the wave is rotating anticlockwise, or Right hand circularly polarized (RHCP) which denotes a clockwise rotation. The main advantage of using CP is that regardless of receiver orientation, it will always receive a component of the signal. This is due to the resulting wave having an angular variation.

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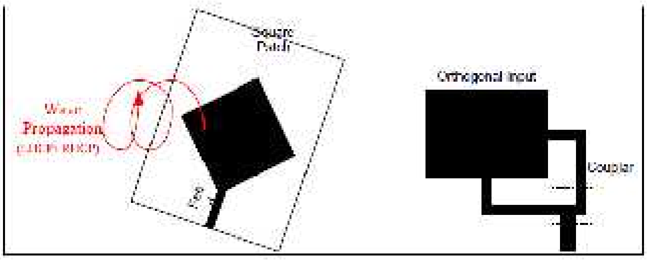

Fig. 3 Circular Polarization

BANDWIDTH

The bandwidth of the patch is defined as the frequency range over which it is matched with that of the feed line within specified limits. In other words, the frequency range over which the antenna will perform satisfactorily. This means the channels have larger usable frequency range and thus results in increased transmission. The bandwidth of an antenna is usually defined by the acceptable standing wave ratio (SWR) value over the concerned frequency range. The fig 4 shows a typical broadband phenomenon in terms of frequency band usage.

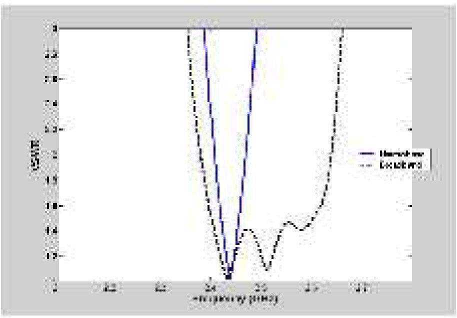

Fig. 4 Narrowband vs. Broadband

Most commercial antennas use a 1.5:1 ratio, as shown in fig 5, suggesting that the range that is covered between the SWR of 1 up to 1.5 is the bandwidth. To ensure comparability with the commercial products, a decision was made to use a 1.5:1 ratio to calculate the bandwidth of antennas.

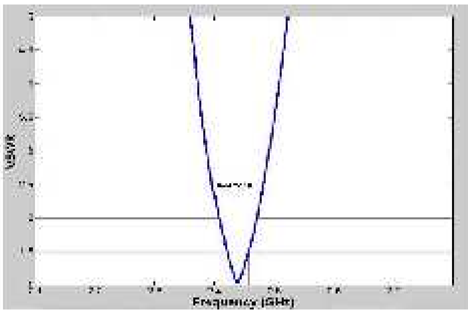

Fig.5 Bandwidth Measurement

III. RESONANT LINE METHOD

Accurately determining the dielectric constant Ɛr is critical to the antenna design process when designing broadband antennas. The Resonant Line method was chosen due to its ease of implementation and the return of accurate approximations. This method uses two microstrip transmission line structures as shown below:

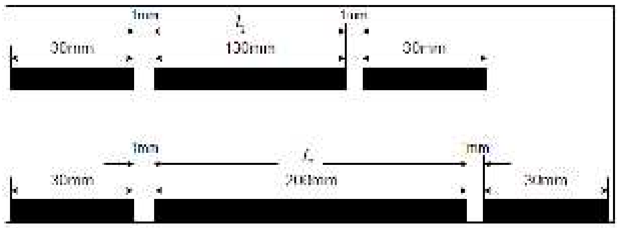

Fig. 7 Implementation of resonant line method

When a signal is fed into the input port, the gaps act as open circuits and in turn set up zero current at these points. When the signal frequency has a wavelength that is a factor (eg. λ/ 2, λ etc) of the length of the centre section, the received signal at the output port will peak. The output will peak every time the signal wavelength matches the integral number of λ/ 2 of the centre section. The wavelength (λ) is known and frequency of the signal can be observed using the network analyser. The length 2l is twice the size of length 1l to compensate for the

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fringing effect at the ends of the patch. The equations (1) and (2) can be used to work out the dielectric constants, ε_{eff} and ε_r:

$$\varepsilon_{eff} = \left[\frac{c(n_1 f_2 - n_2 f_1)}{2 f_1 f_2 (L_2 - L_1)}\right]^2 \quad (1)$$

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

The results suggested an average value of 4.4 for the ε_r. This ε_r value is lower than the G10 substrate permittivity. A possible reason for this could be the use of the new milling machine. When stripping the extra copper from the substrate, the machine removed a significant amount of substrate resulting in reduced height and ripples along the substrate plane.

- COPPER TAPE

The patches made from the copper tape, can be placed on single copper sided sheets of substrate and allow the user to create their own micro strip patch antennas without the use of any industrial machines or etching process. The copper tape allowed us to cut the copper tape to fit calculated dimensions and create desired micro strip patches. One side of the tape was adhesive, so it was possible to fix them on the substrates and in some cases overlap them. The tests show (fig 8) the difference between copper strip and overlapped copper tape is minimal and can be ignored.

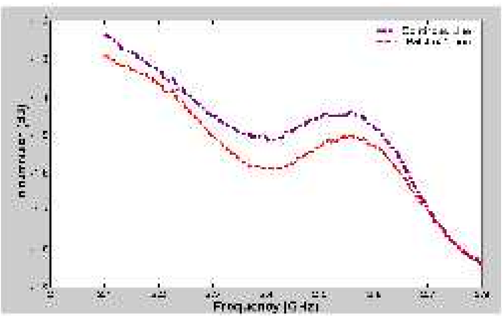

Fig. 8 Conductivity of copper tape

- RECTANGULAR PATCH

The purpose of manufacturing a rectangular narrowband patch was to gain some of the insights to the patch design process. Based on the measurements acquired from the narrowband rectangular antenna, the broadband antennas were designed. Especially to calculate the probe feed coordinates and the iterative process involved. The linearly polarized narrowband antenna was designed to operate at 2.45 GHz with input impedance of 50 ohms, using G10 fiberglass substrate.

Dimensions

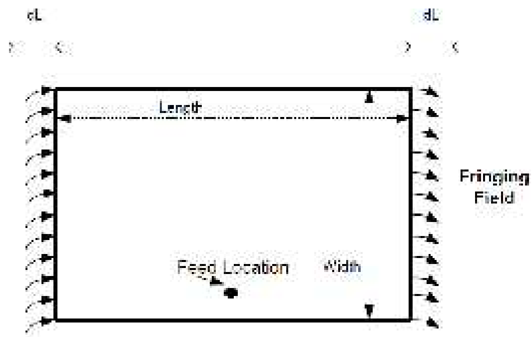

Fig. 9 Narrowband Rectangular Patch Antenna

Length

The length of the patch determines the resonant frequency thus it is a critical factor because it is a narrowband patch. The equation shown below was used to calculate the length of the patch. Since the fringing field cannot be accounted for accurately none of the results are definite.

$$L = \frac{c}{2 f_r \sqrt{\varepsilon_{eff}}} - 2 \times dL \quad (3)$$

For Frequencies below 2 GHz, the variation in L with h is almost negligible. This is a good approximation, as long as resonant frequency (f_r) is less than 2GHz. The dL is the length extension due to the fringing field and can be calculated using the eq. no. 4.

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$$dL = 0.412h\frac{(\varepsilon_{eff}+0.3)(W/h+0.264)}{(\varepsilon_{eff}-0.258)(W/h+0.8)} \quad (4)$$

Width

The width is critical in terms of power efficiency, antenna impedance and bandwidth. It is largely dependent on the operating frequency and the substrate dielectric constant. The equation below was used to work out the width of the patch. Other width should have been used but if it is too small then radiator efficiency will suffer and if it is too large higher order modes will be excited, resulting in field distortions.

$$W = \frac{C}{2f_r}\left(\frac{\varepsilon_r+1}{2}\right)^{-1/2} \quad (5)$$

The theoretical width was calculated to be 37.86 mm.

Co-axial Probe Feed

An advantage of this technique is that it can be placed at any location, and the impedance match will depend on its location on the patch. we can approximate the feed coordinate[1], which would match the input impedance to a 50-Ohm feeder. An improved impedance match will ideally increase the bandwidth, the return loss and improve performance by reducing the excitation of unwanted modes of radiation. The feed co-ordinates were calculated using the following equation:

$$Y_f\,(\text{along the width}) = \frac{W}{2} \quad (6)$$

$$X_f\,(\text{along the length}) = \frac{L}{2\sqrt{\xi_{re}(l)}} \quad \text{where } \xi_{re}(l) = \frac{\varepsilon_r+1}{2}+\frac{\varepsilon_r-1}{2}\left(1+12\frac{h}{L}\right)^{-1/2} \quad (7)$$

The calculated feed coordinates for the given rectangular patch operating at 2.45 GHz are Y_f = 7.52 mm and X_f = 18.79 mm. It is very much an iterative process, to work out the exact co-ordinates that will match the impedance of the feed line to the antenna. Using the Network analyser, the following coordinates returned the best impedance match. AT Y_f = 7.00 mm and X_f = 20 mm, at an input impedance of 49.84–0.012j ohms.

Measurements:

The Fig. 10 shows the SWR response of the rectangular input impedance matched antenna, using the HP8510 network analyser.

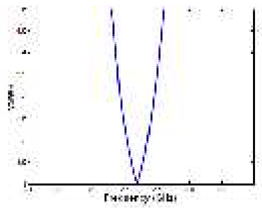

Fig. 10 VSWR response Narrowband Rectangular Patch antenna

IV. BROADBANDING SCHEMES

RECTANGULAR BROADBAND PATCH USING PARASITIC RINGS

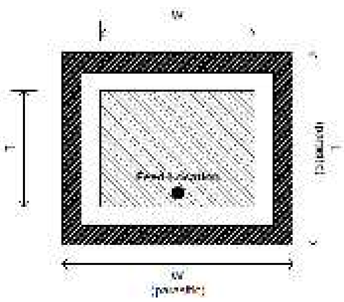

Fig. 11 Rectangular Patch with the addition of parasitic ring

The scheme indicated reduced real estate without sacrificing bandwidth. Following the general design shown in fig 11, ‘t’ is the thickness of the parasitic ring and ‘d’ is the gap between the parasitic ring and the base resonator. A number of patches

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were designed, all of varying, ‘t’ and ‘d’, so the changes could be observed. Unfortunately none of the patches showed any broadband activities.

The research suggested, the length of the parasitic ring cannot be larger than the base resonator which controlled the base resonant frequency. This would suggest, the result of having a ring larger than the base patch would cause the ring to resonate at a frequency outside the 2.4 - 2.5 GHz range. It is also noted that, reducing the gap between the base patch and the ring would increase coupling and increase radiation and possibly increase bandwidth.

RECTANGULAR BROADBAND ANTENNA

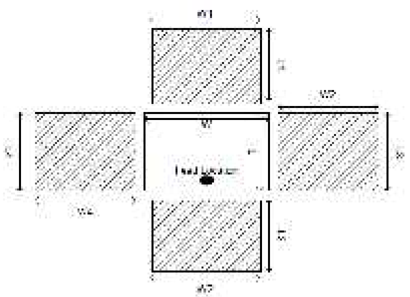

Fig. 12 Broadband using Rectangular Patches

In this method, instead of using parasitic rings, parasitic patches of similar dimensions are placed around the base fed-patch. Operation of the parasitic are same as the base patch as in the length of the parasitic patch determines the resonant frequency and the width sets the bandwidth. The fig. 12 shown above is a typical topographical layout of a four parasitic element patch antenna. It is important to note that the parasitic element dimensions are not identical to each other. By changing individual dimensions it is possible to tune the antenna to achieve the best possible broadband solution. It is important to keep in mind that, it is hard to notice the difference caused by altering the dimensions of one parasitic element. But rather, all four elements need to be altered together in a logical manner in order to achieve the overall broadband solution.

Initially when designing the antenna, all four parasitic elements had identical dimension as the base patch. Subsequently the lengths of the parasitic elements were altered until the required resonant frequencies were achieved. It soon became apparent due to the addition of parasitic elements, the feed location needed to be changed in order to provide the optimum input impedance match. The effect of shifting the feed location 3mm closer can be seen in fig. 12.

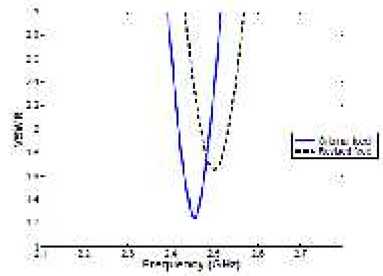

Fig. 13 Effect of changing Feed location

Even though at first the SWR reflected a poor impedance match, as shown in fig 13, the positive effects of shift became apparent after adding the first parasitic element.

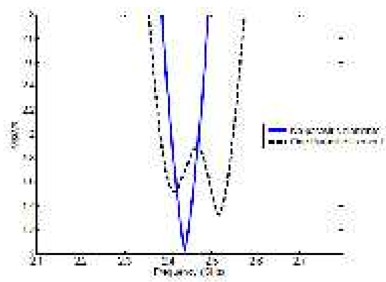

Fig. 14 Effect of adding 1 parasitic patch

The resulting broadband behaviour is obvious from the fig 14 above but the resulting bandwidth was not acceptable. It returned a bandwidth of only 31 MHz (VSWR 1.5:1) covering the 2.501 GHz to 2.532 GHz frequency range.

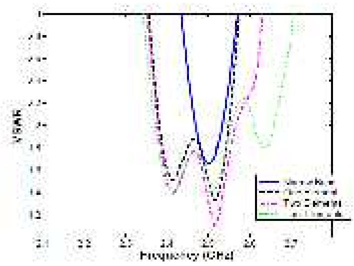

Fig. 15 VSWR response showing the effect of adding parasitic patches

The eventual emergence of the rectangular parasitic patch antenna (fig 15) produced a bandwidth of 185.5 MHz amid VSWR of 2:1 over the frequency range of 2.3695MHz to 2.555MHz. The only noticeable flaw was at frequency 2.47 GHz the VSWR fell outside the 1.5:1 range, resulting in failure to meet stringent commercial specifications.

TRIANGULAR BROADBAND ANTENNA

Triangular patches hold similar attributes as rectangular patches while covering using a smaller area. The triangular patches also have wide half-power beam widths in both planes. Therefore it is suitable for hemispherical application. In this case, an Equilateral Triangular microstrip antenna (ETMSA) is used since they have been known to return a larger bandwidth compared to other triangular antenna.

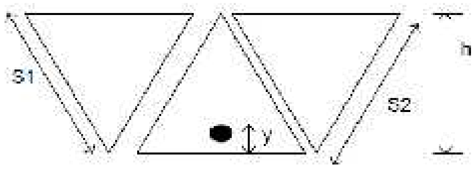

Fig. 16 Triangular Parasitic Patch

Eq. no. 8 will return the dimensions of a triangular patch where f is the lowest order resonant frequency, S is the length of the side arm and ε_r is the substrate permittivity.

$$f = \frac{2C}{3S\sqrt{\varepsilon_r}} \qquad (8)$$

The design method that proved very effective while producing the previous broadband antenna, also proved useful when producing the triangular broadband antenna. Initially the narrowband triangular patch was made using the copper tape and tuned to match the input impedance. The initial construction led to the patch resonating at a frequency higher than 2.45 GHz. numerous attempts were required before the correct dimensions were achieved which allowed the patch to resonate at 2.43 GHz. It was deliberately tuned for 2.43 GHz keeping in mind the frequency shift that will occur from adding parasitic elements. Input impedance was found to be very large at the vertex along the feed axis. The 50-ohm impedance matching can be obtained by feeding the antenna at either above or below the null position at the centre of the patch. The optimum feed coordinates were found to be Y_f = 19 mm, X_f= 19 mm, where the narrow band antenna returned an input impedance of 47.66+0.76j ohms. Fig 16 shows the performance of a matched narrowband triangular patch. The narrowband antenna had a bandwidth of 91 MHz using 2:1 VSWR and 53 MHz using 1.5:1 VSWR.

The next step was to add a parasitic element designed to resonate at 2.48 GHz, resulting in a BW spread in the 2.5 GHz direction. The fig 18 shows the effect of adding one extra parasitic ring. Even though the performance was promising, the return loss showed the power outage was lacking. It was found that the best way to tune these antennas is to follow the changes in smith chart. Looking at fig 17 we can see the narrowband has no loop in its smith chart. The aim is to create the loops by adding parasitic elements but also tune the antenna so the loops are situated around the centre of the smith chart. This will ensure a good input impedance match over a larger range of frequencies. Larger loops provide greater BW extension, and this is evident from the BLACK plot in the smith chart which is the final antenna and it has the largest loops and all centred on the midpoint in the smith chart.

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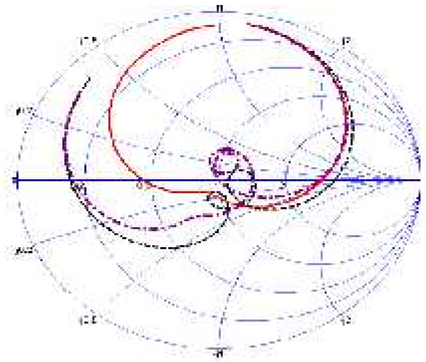


Fig. 17 Smith chart showing the input impedance of all triangular broadband patch over 2.1 - 2.8 GHz

With the addition of the second parasitic element, resonating at a slightly lower frequency, the extra dip in the SWR plot was added. This extended the coverage in the 2.4 GHz end of the frequency band. It was also found that overall resonance range could be shifted not only by the dimensions alone but also the gap between the parasitic and base element. By utilizing this feature, it is possible to keep one end of the resonant band stable while extending the other end of the frequency band. As a result the parasitic elements of the ETMSA are not symmetrically distanced from the base resonator.

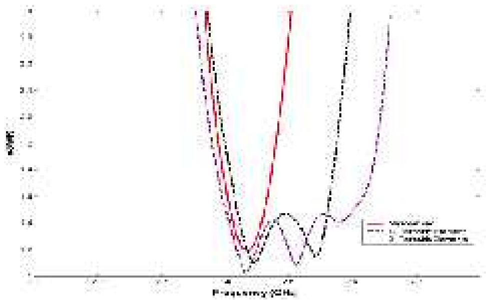


Fig. 18 VSWR response showing the effect of addition of triangular parasitic patch

The matching process is somewhat different for the gap coupled parasitic resonators. The input impedance of the base resonator needs to be greater than 50 ohms since the addition of the parasitic elements will create the loops that pull down the overall impedance resulting in a closer match at the desired frequencies. Using the HP8510 network analyser, it is possible to show (fig 18) that the triangular ETMSA produced a 259 MHz bandwidth using VSWR 2:1 and 198 MHz using VSWR 1.5:1. Using VSWR 2:1, the bandwidth of the triangular antenna is 2.85 times greater than the narrowband antenna and 1.4 times greater than the rectangular broadband antenna. The triangular broadband also produced a maximum of 42.535 dB return loss at 2.4325 GHz. Please refer to Appendix-G for return loss response of the antennas. Also The Patch real estate required for the triangular is 90 cm2 compared to the 210.6 cm2 for the rectangular patch. As the fig 19 illustrates, the triangular has a larger bandwidth and produces a greater maximum return loss. But at a higher frequency, the parasitic element is resonant, and therefore experiences a large phase delay with respect to the base resonator; hence the beam maximum shifts away from the broadside.

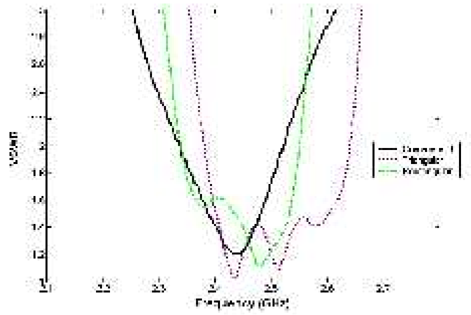


Fig. 19 VSWR response of two in-house broadband antennas against the commercial broadband antenna

V. AREA COVERAGE MEASUREMENTS

Instead of using an anechoic chamber to estimate the radiation pattern using the electric and magnetic field, the decision was made to use Alex Wong's testing apparatus. The testing equipment calculates the path of loss of each of the antennas at different spots of a room. High frequency signal generators were used to feed the antennas. And using radio receiver and a balun based stepper motor driven antenna, 360 samples of path loss are taken for the three resonating antennas. The average path loss of the 360 samples is taken to be the path loss of the antenna at a given spot in the room. The two broad band antennas were tested along with the commercial antenna, and the results were compared to benchmark the in-house antennas. Three resonating frequencies were chosen, 100 KHz apart, for the three antennas. However the return losses of the antennas are not constant and they are very dissimilar. We had to be careful not to pick a frequency that returned a very high return loss for one antenna but comparatively poor return loss for the other two. As a result, to reduce bias, three frequencies were chosen that provided almost identical return losses for all three antennas, as shown in fig 20.

	Triangular	Rectangular	Commercial
Frequency (MHz)	2459	2456	2460
Return Loss (dB)	-13	-13.5	-14

Fig. 20 Table of frequency used for each antenna

As shown in fig 21, in terms field performance the commercial antenna outperforms the in-house antennas. It is also evident that, in most cases the rectangular antenna performs better than the triangular antenna. The overall maximum difference between the commercial and the in-house antennas is approximately 10 db.

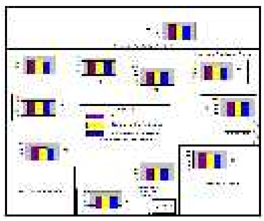


Fig. 21 Area Coverage shown in terms of path loss (dB)

RESONANT LINE MEASUREMENT METHOD AND RESULTS

Step 1: Calculate the width to return 50-ohm impedance.

Step 2: Use portal to design PCB consisting of 2 resonant line structures.

Step 3: Manufacture the board keeping in mind the 1-week manufacture delay.

Step 4: When the board returns, separate the boards in order to eliminate mutual coupling.

Step 5: Attach the connectors.

Step 6: Calibrate the analyser. The calibration procedure can be found in the analyser documentation.

Step 7: connect the board on to the analyser.

Step 8: Record the Resonant peaks seen on the monitor of the analyser using a frequency sweep of 45 MHz to 5 GHz.

Step 9: Using eq. no. 2 calculates the ε_{eff} for each set consisting of resonances from both lengths. Take the average value of the ε_{eff} calculated and apply eq. no. 3 to work out their L value.

Step 10: Have the ε_r assessed the validity of the ε_r value. The ε_r needs to be considered carefully since the milling machine used on the PCB produced uneven substrate height. This may have added error giving us incorrect ε_r values.

Results:

Average ε_{eff} = 3.30

Using the appropriate equation the average ε_r= 4.43.

DIMENSIONS OF RECTANGULAR PATCH

(Using eq. no. 4, 5 and 6)

Length Calculations:

The length extension due Fringing field:

dL (m)	0.000614

The Length of the Patch:

Length (m)		
No fringe	With fringe	Using length extension
0.029780368	0.006505	0.029653949

L used (m)
0.029653949

Implementation:

dL (m)	=(0.412*K8*((B16+0.3)*(E12+0.264))/((B18-0.258)*(E12+0.8)))

Length (m)		
No fringe	With fringe	Using length extension
=$I$5/(2*$I$8*SQRT($I$4))	=$I$5/(2*$I$6)/SQRT($K$4))	=($I$5/(2*$I$8*SQRT($E$18)))-(2*$K$5)

Width Calculations:

Width (m)	Patch width/height
0.03786076	23.66296

Implementation:

Width (m)	Patch width/height
=((($I$5/(2*$I$6))*(((($I$4)+1)/2)^(-0.5)))	=B12/K8

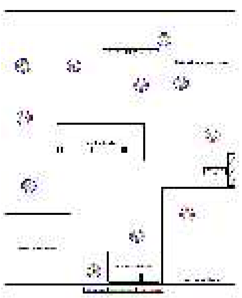
AREA COVERAGE SPOTS AND MEASUREMENT RESULTS

Table below shows the comparison in terms of return loss (dB) different spots in the room

TABLE I

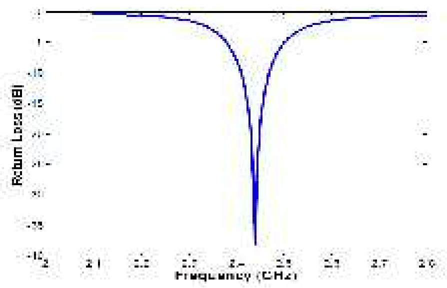
VISUAL ILLUSTRATION SHOWING THE INDIVIDUAL SPOTS AND THE RESPECTIVE PATH LOSSES

Frequency (MHz)	2458	2459	2460
Patch Design	Triangle (dB)	Rectangular (dB)	Commercial (dB)
1	-73.47	-80.11	-74.44
2	-77.27	-76.89	-72.02
3	-68.33	-85.56	-78.77
4	-68.86	-69.82	-61.27
5	-71.43	-70.34	-65.51
6	-73.7	-73.31	-68.04
7	84.54	81.23	76.65
8	74.2	71.46	67.62
9	-75.41	-72.91	-60.00
10	-77.73	-74.2	-69.42
11	-75.59	-73.86	-70.13

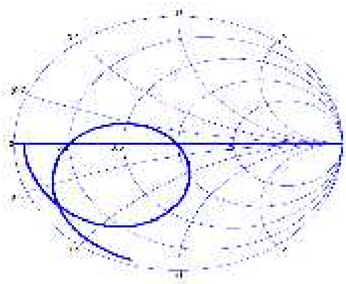


NARROWBAND RECTANGULAR PATCH ANTENNA

Return Loss response of the impedance matched Narrowband Rectangular patch antenna

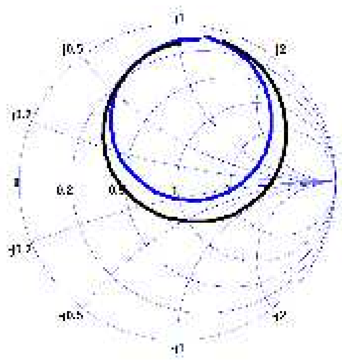


Smith chart plot illustrating Input Impedance of the Narrowband Rectangular patch



BROADBAND RECTANGULAR PATCH ANTENNA

Smith chart illustrating in black the change in Input Impedance due to feed location shift



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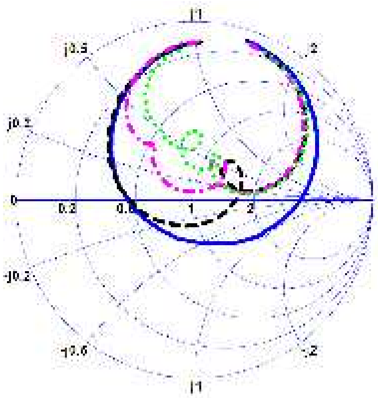
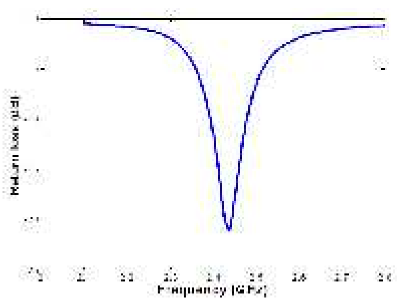
Smith chart illustrating the change in Input Impedance due to addition of parasitic

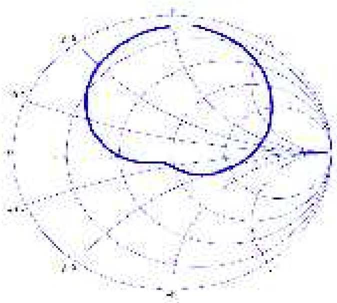


NARROWBAND TRIANGULARR PATCH ANTENNA

Return Loss response of the impedance matched Narrowband Rectangular patch antenna

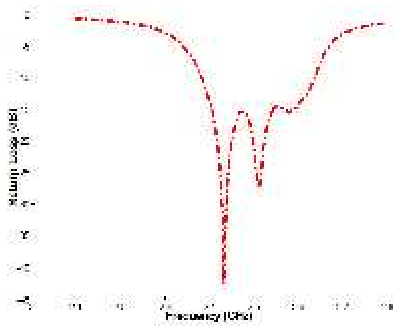


Input Impedance Plot for Matched Narrowband Triangular Antenna



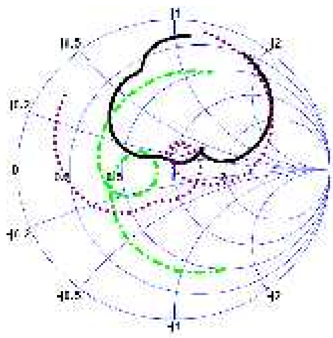
BROADBAND TRIANGULARR PATCH ANTENNA

Return Loss response of the broadband triangular patch antenna



BROADBAND ANTENNA COMPARISON

Input Impedance Plot illustrating the difference between in-house antennas vs. commercial



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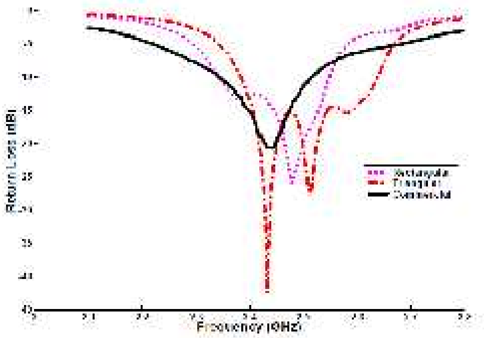
Return Loss response illustrating the difference between in-house antennas vs. commercial



VI. CONCLUSIONS

From the work conducted on broadband patch antennas it is apparent the feasibility of microstrip patch antennas for use in broadband wireless LAN systems utilizing the 2.45 GHz ISM band. Though the disadvantages often limit antenna performance and efficiency, it is however possible to overcome the difficulties and tailor the antennas to suit the specifications. The 2.45 GHz ISM band spans from 2.4 GHz up to 2.5 GHz, offering a total active bandwidth of 100 MHz. As a result the antennas were required to possess a minimum bandwidth of 100 MHz.

The broadband antennas were successfully implemented using adhesive copper tapes and show promising results in terms of broadband performance. For the purposes of this project, two broadband antenna were manufactured both implementing the use parasitic element approach. The first antenna was made from a narrowband rectangular patch antenna designed to resonate at 2.45 GHz, hence four parasitic rectangular patches were added resulting in a bandwidth of 180 MHz using a VSWR of 1.6:1 and 214 MHz using VSWR of 2.0:1. The production of the second antenna was motivated by the key ideas of bandwidth improvement, reduced real estate and input impedance enhancement. Similar scheme was used to produce the second broadband antenna, where a triangular patch was used. Using the triangular patch the bandwidth increased to 259MHz using VSWR of 2:1 and 198 MHz using VSWR of 1.5:1. And the above results were achieved by use of two parasitic elements as opposed four elements required for the rectangular patch, which reduced the real estate area from 210.6 cm2 to 90 cm2.

When the bandwidths of the in-house antenna were compared to the commercial product, the results paint a favourable picture. The commercial broadband antenna returned a bandwidth of 188 MHz using a VSWR of 2:1 as opposed to 259 MHz from the triangular patch antenna. But

under area coverage testing, the in-house antenna under-performed compared to the commercial product. The cause of the phenomenon is possibly due to the use of parasitic

The in-house antennas have performed adequately and managed to meet the specifications. But my project partner and myself feel that the performance of the antennas have been maximized considering the use of substrate and implementation techniques. The performance of the antenna can be further improved by using substrates with low insertion losses as well the emergence of an improved implementation technique.

ACKNOWLEDGMENT

I would like to thank my project partner Mr. Rivansh for his contribution towards the project. I would like to thanks all people for providing us with additional information.

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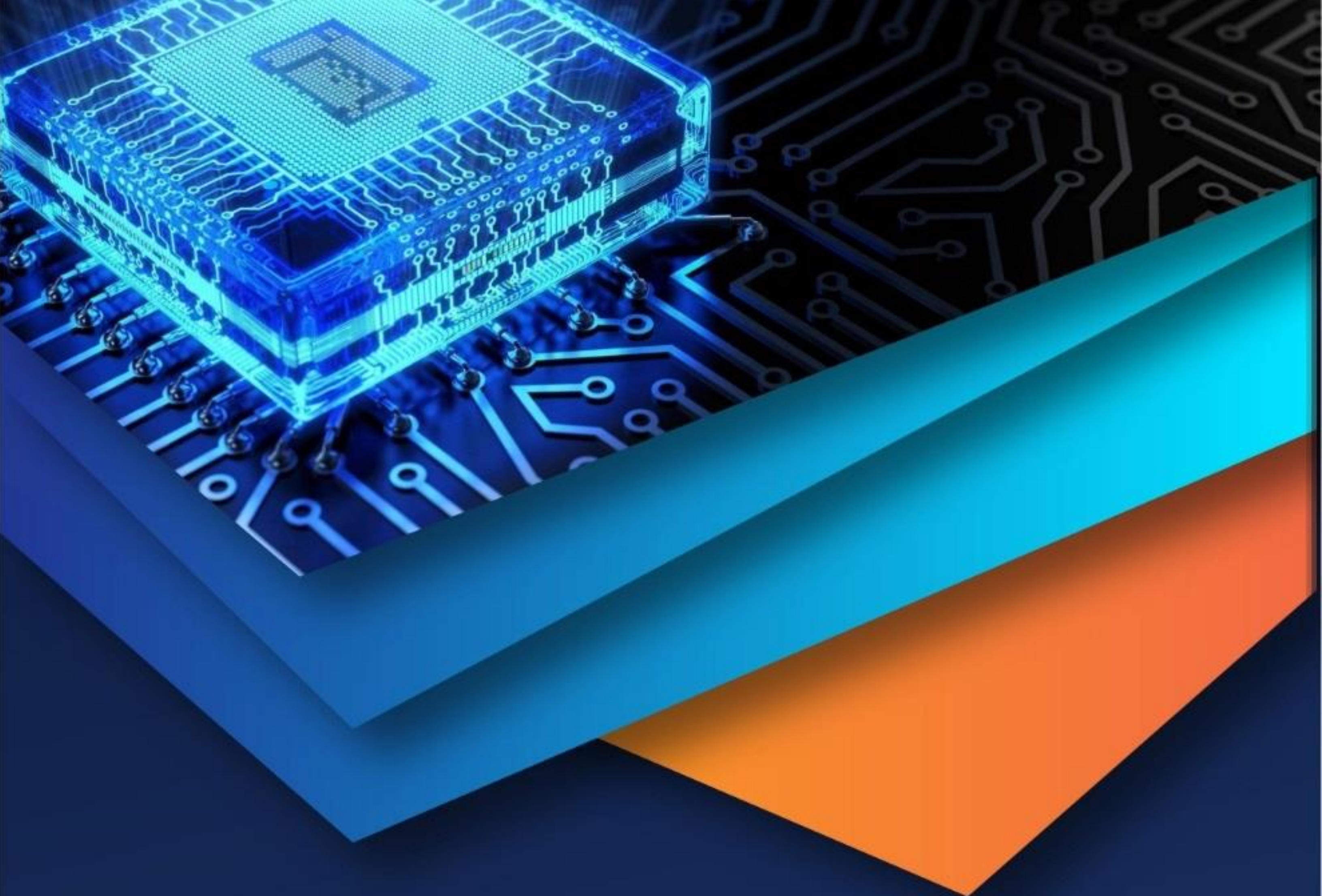

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