

MULTIWAY X-BAND MICROWAVE POWER DIVIDERS FOR ANTENNA ARRAY APPLICATION

THESIS REPORT

*Submitted in partial fulfillment of the requirements for the award of the
Degree of Master of Technology in Electronics and Communication
Engineering with specialization in Communication Systems by the
A P J Abdul Kalam Technological University*

by

POOJA SATHEESH

Reg.No TKM21ECCS09



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ENGINEERING

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CERTIFICATE

Certified that this Project report titled ”**MULTIWAY X-BAND MICROWAVE POWER DIVIDERS FOR ANTENNA ARRAY APPLICATION**” is a bonafide record of the work done by **POOJA SATHEESH** (Reg.No.TKM21ECCS09) under my supervision, in partial fulfillment of the requirements for the award of the Degree of Master of Technology in Electronics and Communication Engineering with specialization in Communication Systems by the A P J Abdul Kalam Technological University.

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ABSTRACT

For spreading or combining microwave signals, power dividers, combiners, and splitters are passive microwave components. Many microwave applications, including phased antenna arrays and power amplifiers, require multiway power dividers. Power dividers come in two different varieties: Wilkinson power dividers and filtering power dividers. Usually, numerous two-way Wilkinson dividers are connected to create planar multiway dividers. Designing multiway power dividers by connecting two-way power dividers is a frequent practise. This divider offers good phase and amplitude consistency between the output ports, as well as good impedance matching at all ports. The two-way dividers are connected using transmission cables. These transmission lines can be used to adjust the two-way dividers performance in addition to serving as a physical connection between them. Calculation shows that only when the electric lengths of the interconnecting transmission lines are multiple quarter-wavelengths do the dividers respond in a symmetrical manner about the centre frequency.

An aperture coupled feeding technique based dual band high gain 4×4 microstrip antenna array has been presented here for X-band radar and satellite communication. The designed array consists of three layers which are corporate feed network, 2D array of radiating patches, and coupling apertures on the ground plane. The novelty of the work is the designing of a new asymmetric H-shaped slot for the aperture coupled antenna (ACA) element. The antenna resonates at dual frequencies at 8.45 and 11.15 GHz within the X-band, those are altered independently by varying the physical parameters of the ACA. The three layers of the array are printed on two Taconic TLY-5 dielectric materials, which are stacked over each other. The designed array is realized on overall size of $100 \times 100 \times 2.09 \text{ mm}^3$ and having return loss bandwidth (BW) of 3.2 percent in both bands that covers frequencies 8.53 to 8.81 GHz and 10.8 to 11.15 GHz. The gain and efficiency of the array are 17.1 dBi and 90.7 percent in the lower band and 19.34 dBi and 94.1 percent in the higher band. The array exhibits considerable low cross-polarization of less than - 14.2 dB and less than - 36.2 dB at two operating frequencies. Design array achieves better gain, and high efficiency on a low profile size. The simulation results display low SLL and high co to Xpol isolation at two frequencies, establishing good radiation characteristics of the array.

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Chapter 1

Introduction

1.1 General Background

For spreading or combining microwave signals, power dividers, combiners, and splitters are passive microwave components. Many microwave applications, including phased antenna arrays and power amplifiers, require multiway power dividers. Power dividers can be made in numerous ways. Widely used dividers are of the Wilkinson type. An N-way Wilkinson power divider, however, is planar only when and not for. Usually, numerous two-way Wilkinson dividers are connected to create planar multiway dividers. It is typically physically challenging to connect the two-way dividers directly with one another in an integrated multiway divider. Additionally, if the two-way dividers are too close to one another, unwanted cross-coupling may be present. Extra transmission lines are typically required to connect the two-way separators in order to keep them apart. It is fascinating to notice that the interconnection of multiway dividers, despite the fact that many have reported on the design and advancement of Wilkinson dividers. The interconnecting transmission lines lengths appear to be picked at random.

Radio frequency (RF) and microwave circuits frequently employ power dividers, one of the most significant passive circuits. Due to its small size and usefulness, the power divider with bandpass-filtering response is appealing. First, low-pass filters or bandpass filters are typically cascaded with a power divider to create a filtering-response power divider. This power divider's size is a drawback, though. There have been produced power dividers with bandpass-filtering responses. One of them

uses capacitively loaded transmission line resonators to provide a power divider with wideband filtering response. To generate an ultra-wideband (UWB) filtering response, slot line, shorted-end coupled lines are employed. A UWB power divider with a sharp roll-off skirt has been built using two stepped-impedance open-circuited stubs and parallel coupled lines. A power divider with a bandpass response is designed using capacitive-loaded transmission line resonators, as opposed to a filtering power divider that is based on parallel coupling.

The planar form of antenna has drawn a lot of interest ever since the development of the microstrip antenna (MA). Due to its advantages over traditional reflector and wire antennas, such as its low profile, light weight, compact size, and ease of integrating lumped components (active or passive), MA has replaced them in wireless-mobile communication, satellite, and radar systems. Modern smartphones, numerous wireless devices, and wireless sensors, such as Bluetooth speakers and wireless chargers, among others, all find applications for MA.

1.2 Objectives

- Conventional MA faces challenges due to narrow BW, low gain.
- Multiband MAs are suitable in the limited space of mobile phone and wireless gadget to satisfy multifunction operations. The multiple resonances are obtained in planar MA by exciting the high order modes, placing the metamaterial resonator or complementary split ring resonator in the patch or ground plane.
- In those methods, it is difficult to achieve desired broadside radiation at multiple frequencies, also low gain at the resonances limits their practical uses for a long-distance wireless communication.
- The gain of MA can be improved by placing frequency selective superstrate, reflector at the back, or designing antenna array.
- The superstrate and reflector enhance the total height of the antenna to quarter wavelength or more, which impairs the low-profile nature of the MA.

- Instead array of radiating patches alongside series or corporate feed network provides very high gain on a low-profile geometry.

1.3 Organization of the thesis

The first chapter of the thesis introduces the concept of power dividers. The second chapter includes a comprehensive review of the literature covering the broad area of power dividers. The third chapter focuses on designing of power dividers which include 1x4 and 1x8, designing of dual band ACA array and filtering ACA array. The fourth chapter details the results and discusses the interpretations and findings. The last chapter deals with conclusion and future scope followed by references.

Chapter 2

Literature Review

This section, presents an overview of some works related to the proposed approach.

Yuan Chun Li *et.al.*, [1] proposed a Dual-Band Power Dividers Integrated With Bandpass Filters. This paper describes a unique device that combines two bandpass filters and a power divider. It has the ability to simultaneously split electricity and choose frequency. At the centre frequency, it is discovered that the filter's phase shift is 90 degrees. Consequently, it can take the place of the traditional quarter-wave length transmission line in the power divider when it is matched to 70.7ohm. The filter's phase characteristic is researched. The standard transmission lines can be replaced with filters acting as impedance transformers. To achieve a good isolation, a combination of resistors, capacitors, or inductors is loaded at the open ends of the filters rather than just pure resistance. The proposed structure's reduced size and improved circuit integration are made possible by the isolation elements' unique location. The design is guided by the even- and odd-mode technique. Power dividers are integrated with single- and dual-band BPFs in order to validate the hypothesis. The proposed power divider filter can divide the signal into two equal portions and choose the required frequency band, according to the agreement of the simulated and measured findings.

Shan Gao *et.al.*, [2] proposed a Novel Wideband Bandpass Power Divider with Harmonic-Suppressed Ring Resonator. A novel wideband bandpass power divider with good in-band responses and out-of-band harmonic suppression is described using a straightforward stub-loaded ring resonator. The ring resonator's initial two resonances are aroused and used to build a wideband passband. Four transmission zeros

can be produced in the lower and upper stopbands by varying the length of loaded open stubs. Three coupled-line sections are installed at one input port, two output ports, two additional in-band poles and one upper-stopband transmission zero along the ring. After that, five gearbox zeros are used in total to reduce high-order harmonics and increase passband selectivity. They describe a wideband bandpass power divider based on a straightforward harmonic-suppressed ring resonator. The first four resonances can be shifted to lower frequencies and combined to generate a large passband along two signal pathways at once by positioning two open-circuited stubs and three coupled-line sections around the ring resonator. At dc and upper stopband, a total of five gearbox zeros can be introduced. The upper stopband bandwidth can then be made wider by totally suppressing the first spurious harmonic close to the wide passband.

Xiu Yin Zhang *et.al.*, [3] proposed a Compact Filtering Power Divider With Enhanced Second-Harmonic Suppression. In this letter, a small power divider with very selective bandpass responses is presented. Five resonators and a resistor are integrated in a new topology to realise the twin roles of power dividing and filtering. Near the passband edges, two transmission zeros are produced, and a third is produced at the second harmonic frequency, increasing the rejection levels. It is suggested to use a unique filtering power divider with improved second-harmonic suppression. A half-wavelength resonator, four quarter-wavelength resonators, an isolation resistor, and these components make up the circuit. Between the two resonators, a resistor is placed to improve isolation and match performance. The resonators that may produce two transmission zeros near the passband borders and one at the second-harmonic frequency are coupled together with mixed electric and magnetic coupling, cross coupling, and cross coupling, respectively. As a result, the out-of-band rejection is superior to our earlier work in that the isolation performance is improved and the size is significantly reduced.

Kaijun Song *et.al.*, [4] proposed a Compact in-phase power divider integrated filtering response using spiral resonator. This paper offers a small in-phase power divider with filtering response. Compact size and bandpass filtering response are goals of spiral resonators. Input and output coupling lines are used to provide a source-load cross-coupling, which improves the frequency selectivity of the power divider

that is being presented. A passband-filtering in-phase power divider that has been designed, built, and tested. The presentation and investigation of a brand-new in-phase power divider with bandpass filtering response. Miniaturisation is accomplished using spiral resonators. Source-load cross-coupling is used to provide two transmission zeros on either side of the passband, improving frequency selectivity and out-of-band rejection. The presented bandpass-filtering-response power divider has demonstrated reasonable frequency selectivity and out-of-band rejection performance in simulations and measurements.

Chi-Feng Chen *et.al.*, [5] proposed a Compact Microstrip Filtering Power Dividers With Good In-Band Isolation Performance. Power dividers (PDs) for microstrip filtering that are small and highly isolating have been introduced. The compact folded net-type resonator is chosen to construct the resonator-based PDs with a filtering response in order to efficiently decrease circuit area. The divider's extremely symmetric construction offers excellent in-band isolation performance as well as minimal magnitude and phase imbalances. Two design examples of in-phase and out-of-phase PDs with second order Chebyshev filtering responses have been created and manufactured using microstrip technology as part of the demonstration. It has been suggested to use microstrip resonator-based PDs that are small and have strong in-band isolation, second-order Chebyshev filtering response, and equal power division. The small folded net-type resonator is selected to work with the divider design, which allows for a significant reduction in the circuit size. Additionally, by adding a highly symmetric coupling structure to the divider, the in-band isolation can be effectively increased. To test the suggested concept, both 0 and 180 filtering PDs with a very small size have been created and put into use for the demonstration.

Bo Zhang *et.al.*, [6] proposed a Wideband filtering power divider with high selectivity. A terminated coupled line structure-based wideband filtering power divider (PD) with good selectivity is shown. The optimisation of the bandwidth tuning, isolation, and impedance matching performances are shown and described. A centre frequency (f_0) of 3.0 GHz and a fractional bandwidth of 70 percent are used in the design and implementation of the filtering PD. The introduction and analysis of a wideband filtering PD with good passband selectivity. A prototype filtering PD with a 3.0 GHz centre frequency and a 70 percent fractional bandwidth (FBW) is built

and measured for verification.

Jin-Dong Zhang *et.al.*, [7] proposed a Dual-Band and Dual-Circularly Polarized Single-Layer Microstrip Array Based on Multiresonant Modes. In this communication, a planar dual-band array having orthogonal circular polarisations (CPs) in the two frequency bands is suggested. The array can easily be expanded to construct a larger array because it is implemented on a single-layer substrate. The edges of a square patch are loaded symmetrically with stubs to create a new antenna element for such an array. In this communication, two orthogonal mode pairs—TM₁₀ / TM₀₁ and TM₃₀ / TM₀₃—are simultaneously activated and used to realise various CP radiation sensors in the two bands. The working theory and design process of this patch are then explained using an equivalent transmission-line model. A 2 by 2 element array prototype working at 2.53 and 3.59 GHz is created to verify its efficacy. In the dual bands, the left- and right-hand CPs are concurrently acquired, and it is discovered that the measured and simulated findings correspond well. 10.8 and 12.5 dBic, respectively, in the lower and higher bands, are the measured radiation gains.

Gang Zhang *et.al.*, [8] proposed a High-Performance Dual-Mode Filtering Power Divider With Simple Layout. In order to implement the twin functions of power division and filtering, a new architecture is developed that only incorporates one resonator and one resistor. Three open-ended stubs are inserted into the input and output of the FPD, respectively, to further enhance its frequency selectivity and obtain a large upper stopband. The increased performance and straightforward design layout of the given FPD set it apart from those in the literature. This letter aims to introduce a novel and straightforward dual-mode FPD design that achieves strong in-band isolation and sharp frequency selectivity with just a single open-type T-shaped resonator. In order to improve the FPD's performance in terms of isolation, a resistor is inserted between the two output lines. The input and output also incorporate three open-ended stubs to create multiple transmission zeros, enhancing the frequency selectivity and harmonic suppression. A dual-mode FPD prototype is used as a demonstration.

Jiaqing Chen *et.al.*, [9] proposed a Dual-band high-gain Fabry-Perot cavity antenna with a shared-aperture FSS layer. Here, a single superstrate layer, dual-band, high-gain Fabry-Perot cavity antenna (FPCA) is presented. A patch antenna and a double-sided frequency selective surface (FSS) superstrate make up the design. This

design's unique quality is that it offers high reflectivity, quasi-optimal reflection phases in two predetermined frequency ranges. A dual-band patch antenna and two parallel reflectors make up the FPCA. The bottom reflector is a metallic ground plane, and the top reflector is a shared-aperture FSS superstrate acting as a PRS. As the feed to the cavity, the dual-band patch antenna is situated in the middle of the baseplate. When a superstrate has quasi-periodic FSS array units on the opposing surfaces, it can give the necessary reflection properties at WLAN and X-band. The suggested FPCA can exhibit dual-band behaviour by merging the FSS superstrate reflection phases.

Chapter 3

Methodology

3.1 Multiway Power Divider

An electronic device called a multiway power divider, often referred to as a power splitter or power combiner, is used in RF and microwave systems to split a single input signal into numerous output signals or to combine multiple input signals into one output signal. The Wilkinson power divider, a passive component that divides input power equitably across its output ports using a mix of resistors and transformers, is the most popular kind of multiway power divider. Many different applications, such as communication systems, test equipment, and radar systems, make use of the Wilkinson power divider.

3.1.1 1 to 4 Way Power Divider

Figure 3.1 shows a schematic of 1x4 equal power divider. An apparatus that divides the input power into two or more output signals with equal or different power levels is referred to as a power divider or power splitter. The input signal is divided into four equal output signals by a 4-way power divider. Circuits like the Wilkinson power divider, rat-race coupler, or hybrid power divider can be used to do this. The power divider needs to be created for the application's particular frequency range. Power dividers come in a variety of designs, including Wilkinson, rat-race, branch-line, and hybrid couplers. The input and output signals' impedances should be the same as the impedance of the power divider. The power delivery to each output port

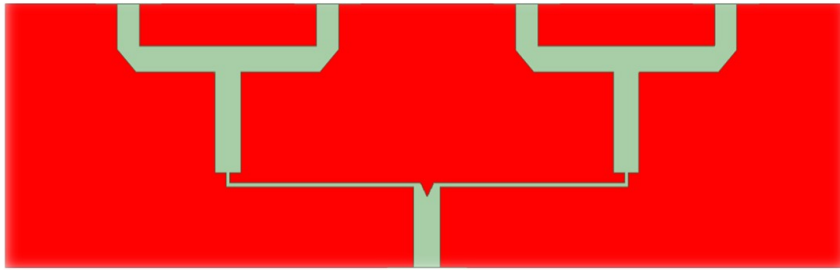


Figure 3.1: Schematic of 1 x 4 equal power divider

as a percentage of the input power is known as the power division ratio. The power division ratio for a 1-to-4-way power divider is 1:4, which means that the input power is split into four equally-sized pieces. The type and level of performance required will determine the power divider's layout. The performance of the power divider will also be impacted by its physical characteristics. The design can be simulated and optimised for the desired performance using the simulation programme Ansys HFSS. It uses Taconic TLY-5 as a substrate.

3.1.2 1 to 8 Way Power Divider

Figure 3.2 shows schematic of 1x8 equal power divider. An 8-way power divider is a power divider that can divide a signal into 8 equal outputs. The output signals will all be in phase with one another and each will have the same power level as the input signal. It's important to remember that different power dividers, such as resistive power dividers and Wilkinson power dividers, are made to split signals in slightly different ways. The fundamental idea is still to divide an input signal into a number of identically powered output signals. The power divider needs to be created for the application's particular frequency range. Power dividers come in a variety of designs, including Wilkinson, rat-race, branch-line, and hybrid couplers. The input and output signals' impedances should be the same as the impedance of the power divider. The power delivery to each output port as a percentage of the input power is known as the power division ratio. The power division ratio for a 1-to-8-way power divider is 1:8, which means that the input power is split into four equally-sized pieces. The type and level of performance required will determine the power divider's layout. The performance of the power divider will also be impacted by its physical characteristics.

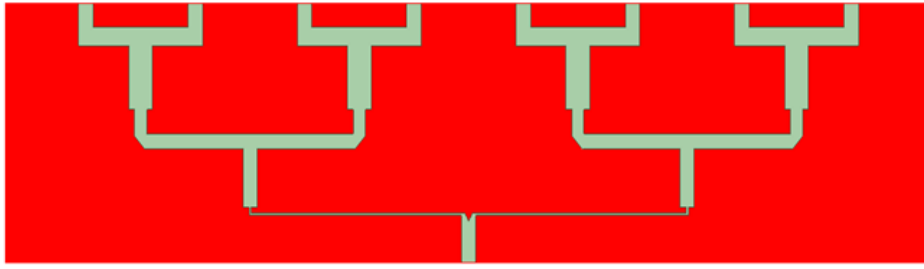


Figure 3.2: Schematic of 1 x 8 equal power divider

The design can be simulated and optimised for the desired performance using the simulation programme Ansys HFSS. It uses Taconic TLY-5 as a substrate.

3.2 Dual Band High Gain Antenna Array Using Aperture Coupled Feeding

3.2.1 Structural Geometry

Figure 3.3 shows 3D view of dual band aperture coupled antenna. Aperture coupling feed in antenna typically consists of microstrip patch, dielectric substrate, ground plane, coupling aperture, feedline and feed network. The radiating component in this construction is the microstrip patch antenna. The patch is attached to the substrate, which is a thin dielectric sheet. The substrate supports the antenna mechanically and aids in regulating the antenna's impedance. The ground offers a conductive surface for the antenna and aids in lowering radiation towards the antenna's rear. The ground plane's coupling aperture is a tiny notch or hole that sits beneath the patch. The connection between the patch and the feed line is controlled by the aperture's size and shape. Aperture coupling method in the present work has been used in order to take the advantages of low cross-polarization and independent adjustment of the feed and radiating patch. The antenna is engraved on the Taconic TLY5 substrates- for which loss tangent is 0.0009, relative permittivity is 2.2. Radiating patch and ground plane with coupling aperture are patterned on front and rear sides of the top substrate of height (h_a) 1.58 mm. Whereas microstrip line with 50 ohm impedance is patterned on the backside of the bottom substrate of height (h_f) 0.51 mm. By engraving new slot geometry in the ground plane of the the ACA, one can obtain dual frequency

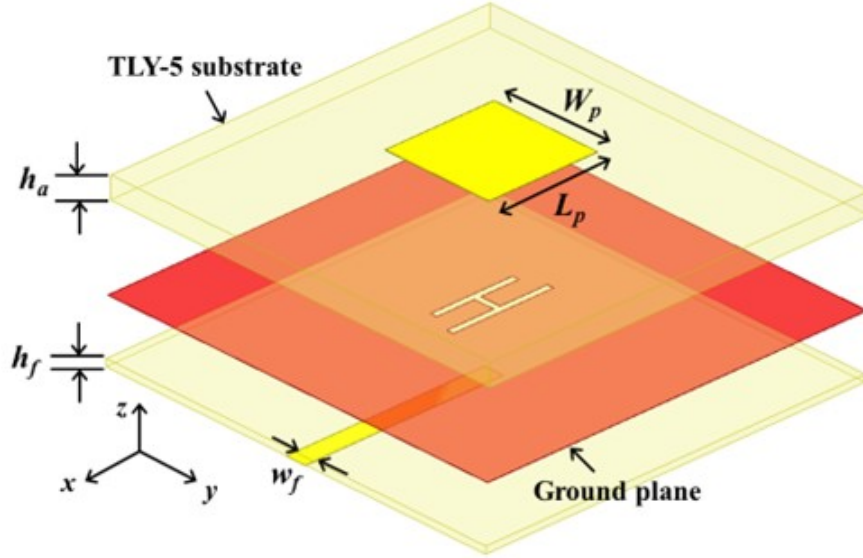


Figure 3.3: 3D view of dual band aperture coupled antenna

resonances. The designed slot has been made in the shape of an asymmetric H shape pattern. Length and width of rectangular shaped patch are 8.6 and 8.2 mm respectively. EM (electromagnetic) signal in the feed line is coupled to the patch using a magnetic coupling technique through the H-shaped aperture. Table 3.1 displays antenna's physical parameters with final dimensions. High frequency structure simulator (HFSS), ver. 20 has been utilized for the design and simulation of the antenna.

Table 3.1: Dimensions of the physical parameters

h_a	h_f	L_p	W_p	w_f	$Ls1$
1.58	0.51	8.6	8.2	1.5	1.52
$Ls2$	$Ls3$	$ws1$	$ws2$	$ws3$	
7.95	6.5	0.5	0.5	0.5	

3.2.2 Design Principle

For explaining dual resonances of the designed antenna, an ACA with a conventional rectangular slot (7 mm x 0.5 mm) is also designed on the same substrates keeping the patch's size as earlier. The conventional ACA resonates at 8.5 GHz and having S11 less than -10 dB from 8.34 -8.71 GHz as shown in Figure 3.4. It is noteworthy to mention that the slot is positioned at center just beneath the rectangular

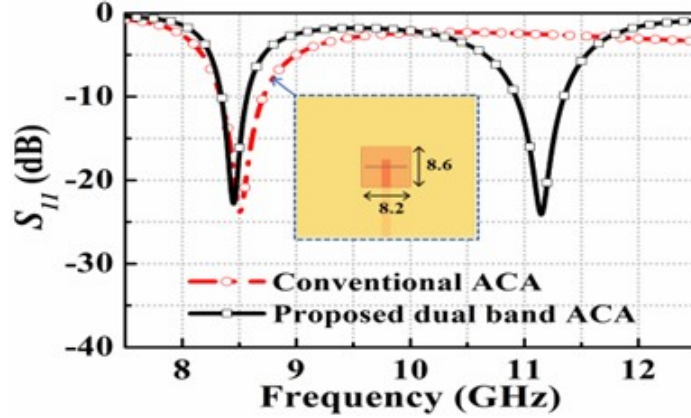


Figure 3.4: Return loss of conventional proposed ACA

patch. At fundamental TM₁₀ mode of resonance, maxima of surface current occurs at patch's center, whereas current is found zero along radiating edges (along y - axis) due to open circuit.

So, coupling of EM wave between patch and aperture is predominantly magnetic in nature. The rectangular aperture is changed into H-shaped pattern whose two vertical arms have different lengths – L_{s2} and L_{s3} . By adjusting length and width of the two arms, one can tune the resonances at desired frequencies.

3.2.3 Parametric Variation and Radiation Characteristics

As mentioned earlier the two resonances of proposed ACA can be modified independently by altering antenna's physical dimensions. For different widths of H-shaped slot and patch's width (W_p), return loss magnitude is determined. Figure 3.5 reveals that the first resonance lowers from 8.55 to 7.95 GHz when w_{s2} increases from 0.4 to 1.2 mm, providing a tuning range of 600 MHz. The change in w_{s2} has negligible impacts on the 2nd resonance frequency, except a slight deterioration in the reflection coefficient magnitude.

The second resonance frequency can be varied independently by changing the width of the patch. The 2nd resonance of ACA varies from 11.65 to 10.9 GHz (within tuning range of 750 MHz) by increasing W_p from 5.8 to 9.8 mm. The resonating modes of designed dual band antenna will be better explained from the surface current distribution at two frequencies – 8.45 and 11.15 GHz.

First resonance is similar to a patch's fundamental TM₁₀mode, for which current

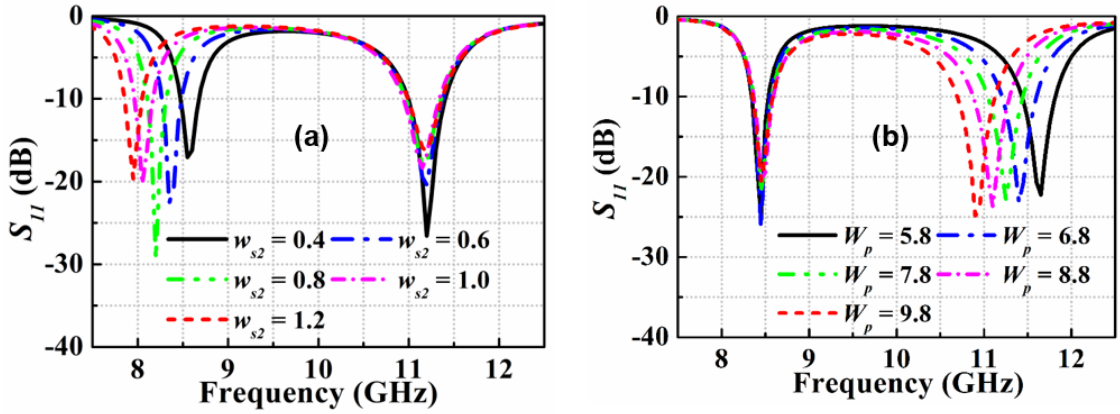


Figure 3.5: Return loss at different values of (a) H-shaped slot width (b) radiating patch width

distributes along the resonating length of the patch. For the second resonance, the current is mostly concentrated at center due to a strong coupling between the patch and H-shaped slot. Surface current shows two half-cycle variation along x-axis, and also in two halves the currents are parallel. Here the second resonance mode is called as even TM₂₀ mode. Unlike the conventional MA for which TM₂₀ resonating mode exhibits broadside radiation null, the proposed antenna shows good broadside radiation at the high order mode due to in-phase current direction similar to TM₁₀.

3.2.4 Design of High Gain Dual Band Array

Gain of proposed dual resonances antenna can be improved by designing a 4 x 4 2D array. The array is fed by a corporate feed network, which equally divides the input power at each output port. Each antenna element of the array radiates individually. The radiation from the elements will add up constructively in the boresight direction due to equal phase power division by the corporate feed network. Fig.3. 6 shows the schematic of each designed aperture coupled dual band array. The lateral size of the array is 100 mm x 100 mm. The spacing between the antenna elements is 21 mm along both x and y directions. At the lower resonance frequency, the spacing between the antenna elements is 0.59 lambda, where lambda is the free space wavelength at 8.5 GHz. In 4x4 designing 1x16 corporate feed network has been used. By using this array design there is benefit of feeding only the input port. Aperture coupling has been used for low cross polarization. The input and output signals' impedances

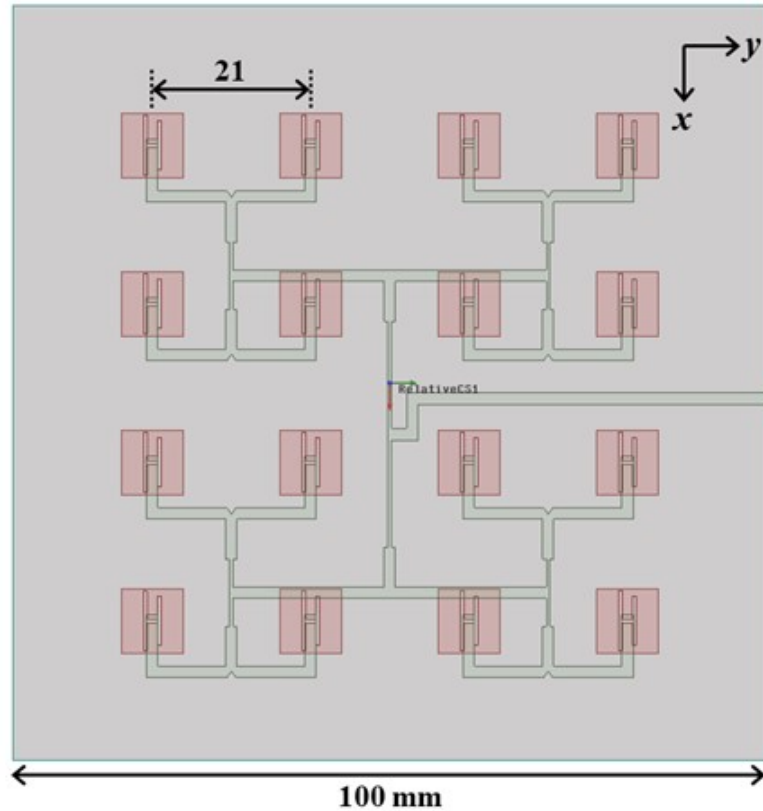


Figure 3.6: Schematic of dual band 4 x 4 aperture coupled array

should be the same as the impedance of the power divider. The power delivery to each output port as a percentage of the input power is known as the power division ratio.

3.3 Filtering Antenna Array

Fig.3. 7 shows the schematic of each designed 2x2 aperture coupled antenna array. Aperture coupling method in the present work has been used in order to take the advantages of low cross-polarization and independent adjustment of the feed and radiating patch. The antenna is engraved on the Taconic TLY5 substrates- for which loss tangent is 0.0009, relative permittivity is 2.2. Radiating patch and ground plane with coupling aperture are patterned on front and rear sides of the top substrate. Whereas microstrip line with 50 ohm impedance is patterned on the backside of the bottom substrate. The designed slot has been made in the shape of a symmetric H shape pattern. Length and width of rectangular shaped patch are 7.92 and 7.95 mm respectively. High frequency structure simulator (HFSS), ver. 20 has been utilized for

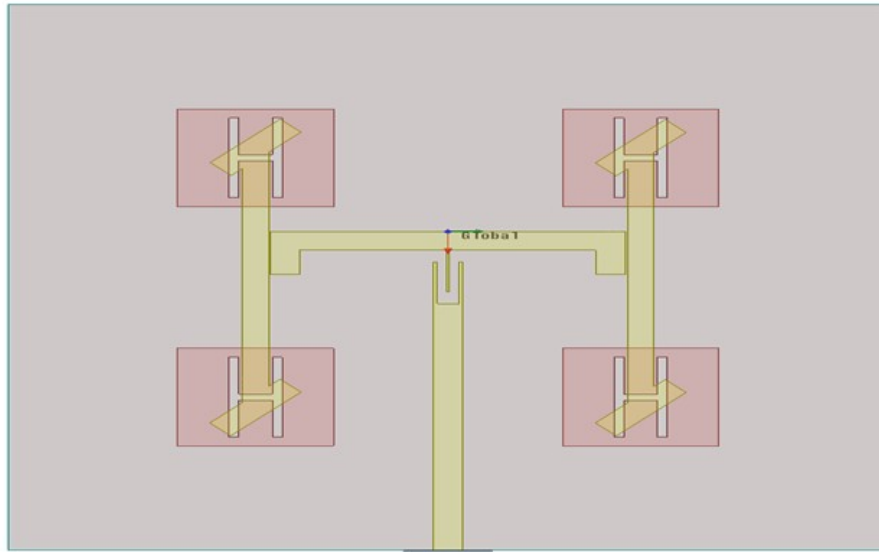


Figure 3.7: Schematic of 2X2 aperture coupled array

the design and simulation of the antenna. The input and output signals' impedances should be the same as the impedance of the power divider. The power delivery to each output port as a percentage of the input power is known as the power division ratio. Table 3.2 displays antenna's physical parameters with final dimensions.

Table 3.2: Dimensions of the physical parameters

h_a	h_f	L_p	W_p	$Ls1$
1.58	0.51	7.92	7.95	1.7
$Ls2$	$Ls3$	$ws1$	$ws2$	$ws3$
6.5	6.5	0.5	0.5	0.5

Chapter 4

Results and Discussions

4.1 Multiway Power Divider

4.1.1 1 to 4 Way Power Divider

The input signal is divided into four equal output signals by a 4-way power divider. Circuits like the Wilkinson power divider, rat-race coupler, or hybrid power divider can be used to do this. The input and output signals' impedances should be the same as the impedance of the power divider. The power delivery to each output port as a percentage of the input power is known as the power division ratio. The power division ratio for a 1-to-4-way power divider is 1:4, which means that the input power is split into four equally-sized pieces. Operating frequency of 1-to-4-way PD is at 10GHz. Simulated return loss is shown at Figure 4.1. Simulated return loss is -40dB. The type and level of performance required will determine the power divider's

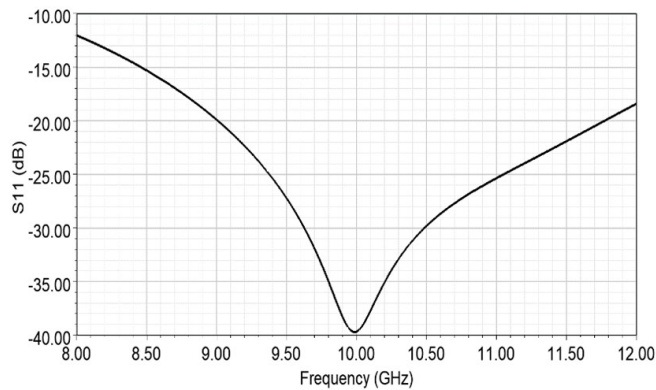


Figure 4.1: Simulated return loss at the input port of 1 x 4 PD

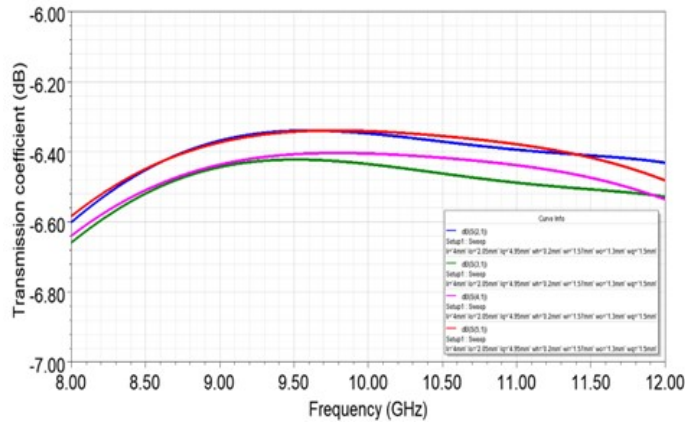


Figure 4.2: Simulated output amplitudes at output ports of 1 x 4 PD

layout. The performance of the power divider will also be impacted by its physical characteristics. Operating frequency of 1-to-4-way PD is at 10GHz. Simulated return loss is shown at Figure 4.1. Simulated return loss is -40dB. Transmission coefficient is approx. -6dB which is shown in Figure 4.2

4.1.2 1 to 8 Way Power Divider

The input signal is divided into eight equal output signals by 8-way power divider. Circuits like the Wilkinson power divider, rat-race coupler, or hybrid power divider can be used to do this. The input and output signals' impedances should be the same as the impedance of the power divider. The power delivery to each output port as a percentage of the input power is known as the power division ratio. The power division ratio for a 1-to-8-way power divider is 1:8, which means that the input power is split into eight equally-sized pieces. The type and level of performance required will determine the power divider's layout. The performance of the power divider will also be impacted by its physical characteristics. The output signals will all be in phase with one another and each will have the same power level as the input signal. It's important to remember that different power dividers, such as resistive power dividers and Wilkinson power dividers, are made to split signals in slightly different ways. The fundamental idea is still to divide an input signal into a number of identically powered output signals.

The quantity of signal reflected back from an antenna as a result of impedance mismatches between the antenna and the transmission line or system it is attached

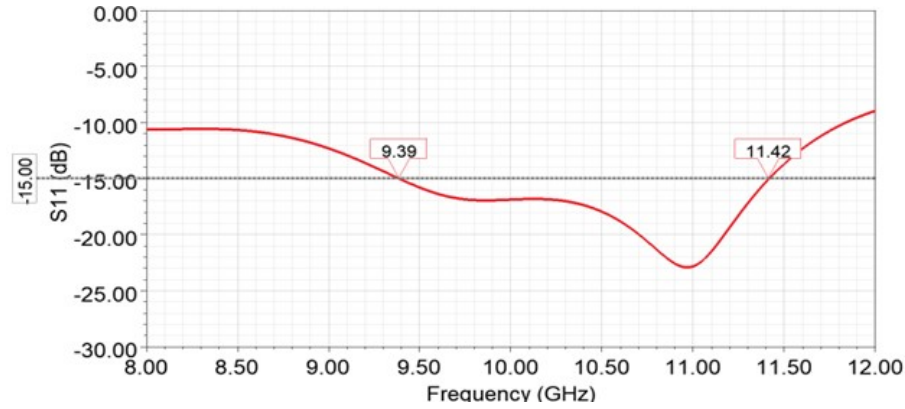


Figure 4.3: Simulated return loss at the input port of 1 x 8 PD

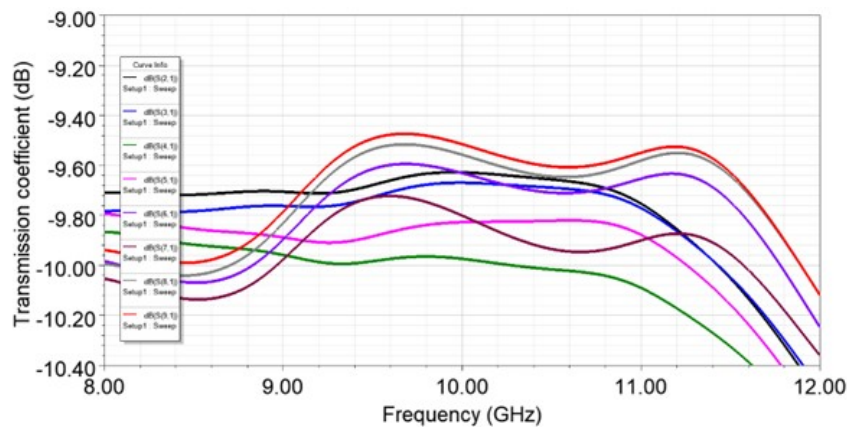


Figure 4.4: Simulated output amplitudes at the output ports of 1 x 8 PD

to is measured as return loss. It is typically measured in decibels (dB) and is represented as a ratio of the power of the incident signal to the power of the reflected signal. Operating frequency of 1-to-8-way PD is at 11GHz. Simulated return loss is -24dB which is shown at Figure 4.3. Transmission coefficient is approx. -9dB which is shown in Figure 4.4

4.2 Dual Band High Gain Antenna Array Using Aperture Coupled Feeding

The quantity of signal reflected back from an antenna as a result of impedance mismatches between the antenna and the transmission line or system it is attached to is measured as return loss. It is typically measured in decibels (dB) and is represented as a ratio of the power of the incident signal to the power of the reflected signal. The 1st and 2nd resonance frequencies of the array has been shifted slightly as compared

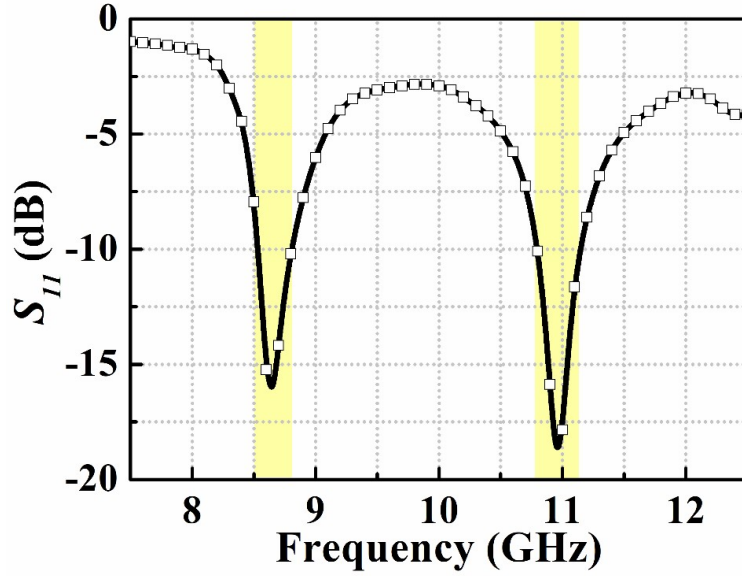


Figure 4.5: Simulated return loss

to single ACA. This may be attributed to the effect of the mutual coupling between the array elements. The simulated return loss of the designed dual band array is depicted in Figure 4.5. The dual resonances of the array occur at 8.65 and 10.95 GHz with a good return loss of 16.55 dB and 19.34 dB respectively. The design array shows reflection coefficient below -10 dB between 8.53 to 8.81 GHz (3.2 percent) in the first band and between 10.8 to 11.15 GHz (3.2 percent) in the second band.

In comparison to a reference antenna, an antenna's gain is a measurement of its capacity to focus or direct electromagnetic energy in a specific direction. It is computed by comparing the power emitted by the antenna in a specific direction to the power that would be produced by an ideal isotropic radiator (a point source of radiation) with the same input power. It is often given in decibels (dB). Alternatively put, an antenna's gain is a measurement of how much more efficiently it radiates energy in a specific direction compared to an isotropic radiator, which radiates energy uniformly in all directions. For instance, if an antenna radiates energy in a certain direction 10 dB more effectively than an isotropic radiator with the same input power, it has a gain in that direction of 10 dB. An antenna's efficiency is determined by comparing the amount of power it radiates to the amount of power it receives. In other words, it is the proportion of input power to radiation power. When expressed as a percentage, an antenna's efficiency typically ranges from a few percent to over 90 percent. High efficiency antennas are used because they radiate more power, enhancing communi-

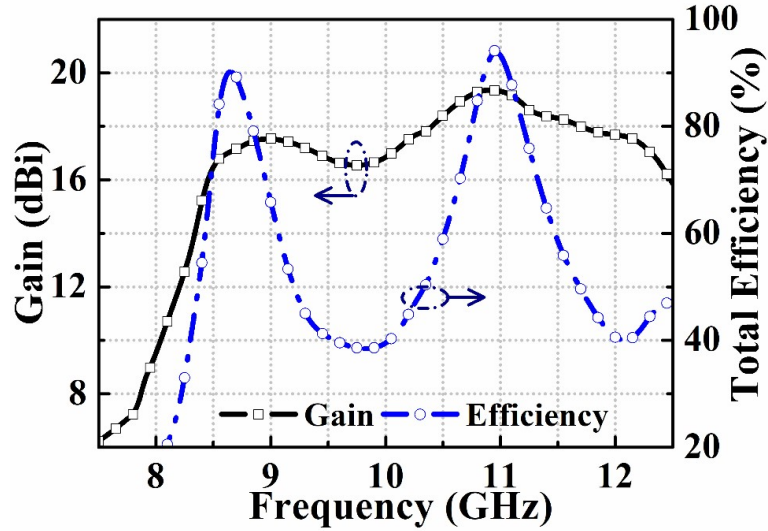


Figure 4.6: Simulated gain and total efficiency

cation and reception. Figure 4.6 reveals the gain and total efficiency of the array. The gain and efficiency of the dual-band array are 17.1 dBi and 90.7 percent at the lower resonance and 19.34 dBi and 94.1 percent at the higher resonance. Within return loss BW, the minimum and maximum gain vary between 16.68 to 17.39 dBi in the 1st band and between 19 to 19.34 dBi in the 2nd band. The efficiencies within the dual-band operating ranges are achieved to be greater than 80.5 percent and 83.9 percent respectively.

Figure 4.7 and Figure 4.8 exhibit array's radiation patterns at two resonant frequencies 8.75 GHz and 10.85 GHz. For ease of representation one can normalize the radiation patterns relative to maximum co-polarized gain. In the both principal planes, dual-band array presents a narrow beamwidth. For two planes, half power beamwidths (HPBW) are 20degree and 22.1degree at the first resonance, and 17.1degree and 16.3degree at second resonance. The SLLs at the two resonances are less than -13.4 dB and less than -13.5 dB in E-plane. In H-plane SLLs are less than -13.5 dB and less than -11 dB for the lower and higher resonances. The designed array exhibits low Xpol power, which can be expected due to aperture coupled feeding technique. Within the 3dB beamwidth of the radiation patterns, the difference between co to Xpol power is obtained to be less than -14.2 dB for 1st resonance and less than -36.2 dB for 2nd resonance. Comparison can be made between dual band ACA array and earlier reported high gain dual band antenna array, as shown in Table 4.1. Design array achieves better gain, and high efficiency on a low profile size as compared to

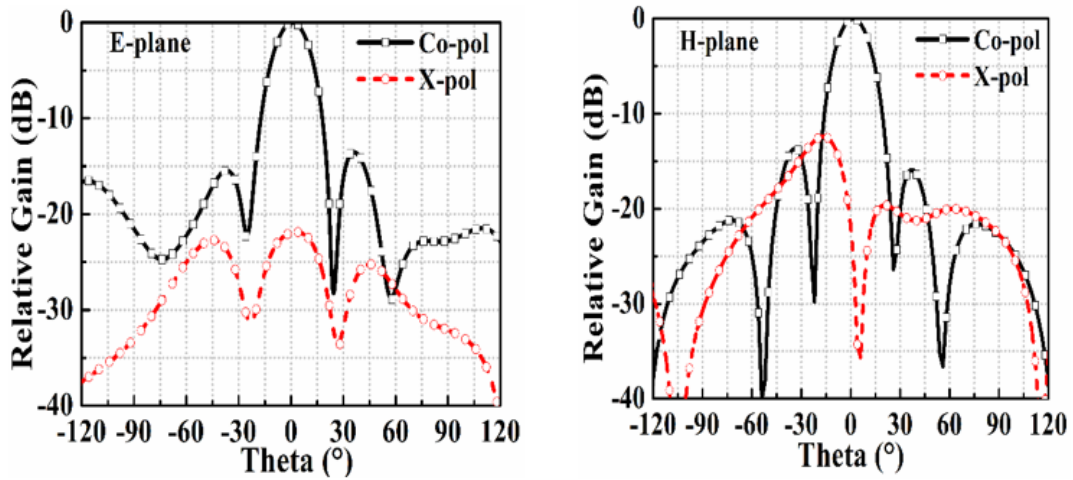


Figure 4.7: E and H plane pattern at 8.65 GHz

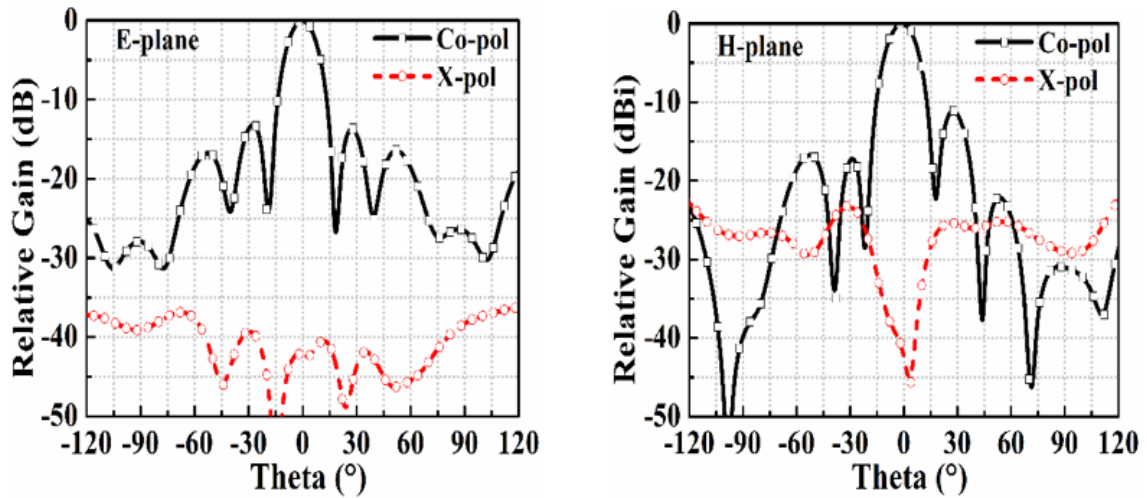


Figure 4.8: E and H plane pattern at 10.95 GHz

the previous antennas.

Wave radiated by the antenna is found to be linearly polarized (x-directed) with considerable high front to back ratio of greater than 10 dB. At two resonant frequencies gain of the antenna are 7.28 and 7.96 dBi. The total efficiencies of the antenna are achieved to be greater than 86.5 percent in lower band and greater 89.6 percent in the higher band. An antenna's efficiency is determined by comparing the amount of power it radiates to the amount of power it receives. In other words, it is the proportion of input power to radiation power. A number of variables, including an antenna's design, frequency of operation, materials utilised, size, and operating environment, all have an impact on how efficient an antenna is. An efficient antenna can be created with

Table 4.1: Comparison of the Dual Resonance ACA Array with earlier Antennas

<i>Ref</i>	<i>freq (GHz)</i>	<i>Gain(dBi)</i>	<i>Efficiency</i>	<i>SLL (dB)</i>	<i>Methods</i>
[9]	5.6,10	10.1,15.2	76.88	17.5,12.7	FSS Superstrate
[7]	2.53,3.59	10.8,12.5	NR	26,11	2X2 array with microstrip feed
<i>This work</i>	8.65,10.95	17.1,19.34	90.7,94.1	13.4,11	4X4 with aperture coupling

high-quality components and the right sizing. Table 4.1 shows comparison of Dual Resonance ACA Array with earlier antennas

4.3 Filtering Antenna Array

When a signal is transmitted from a filtering antenna, the return loss describes the amount of power that is reflected back to the source. It serves as an indicator of the antenna's effectiveness because a high return loss shows that most of the energy is being radiated outward, whereas a low return loss shows that a sizable portion of the energy is being reflected back towards the source. A filtering antenna's specific return loss might change based on its construction and operating frequency. In order to assure effective signal transmission and reception, a well-designed filtering antenna should generally have a high return loss, typically larger than 10 dB.

The simulated return loss of the designed array is depicted in Figure 4.9. The quantity of signal reflected back from an antenna as a result of impedance mismatches between the antenna and the transmission line or system it is attached to is measured as return loss. It is typically measured in decibels (dB) and is represented as a ratio of the power of the incident signal to the power of the reflected signal. In a perfect world, the antenna would radiate 100 percent of the power coming from the transmission line, with no power being reflected back. In practise, there is always some impedance mismatch, and this might result in some of the power being reflected back. Numerous issues, such as diminished signal strength, interference, and decreased antenna efficiency, can be brought on by this reflected power. The array exhibits return loss of -21dB and gain of 8.6dB which is shown in Figure 4.9 and Figure 4.10 respectively

How successfully an antenna transforms input power into radiated power is determined by its radiation efficiency. Radiation efficiency is crucial in filtering antennas

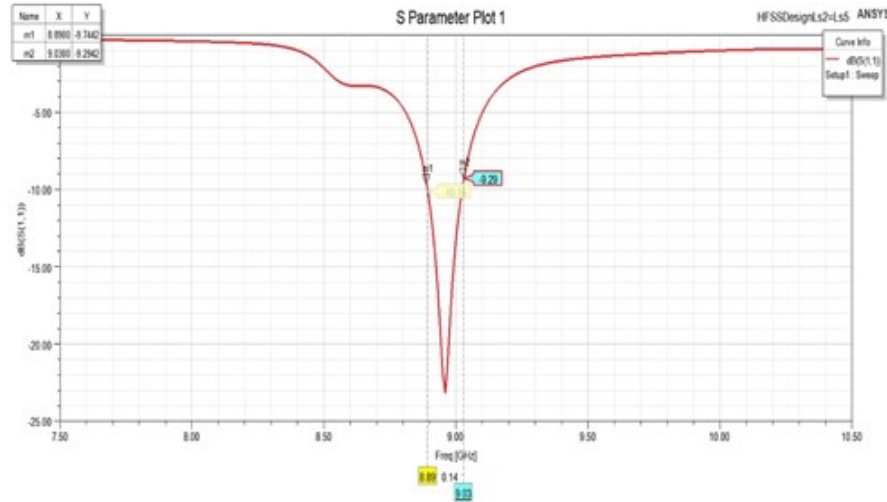


Figure 4.9: Return loss of 2x2 array

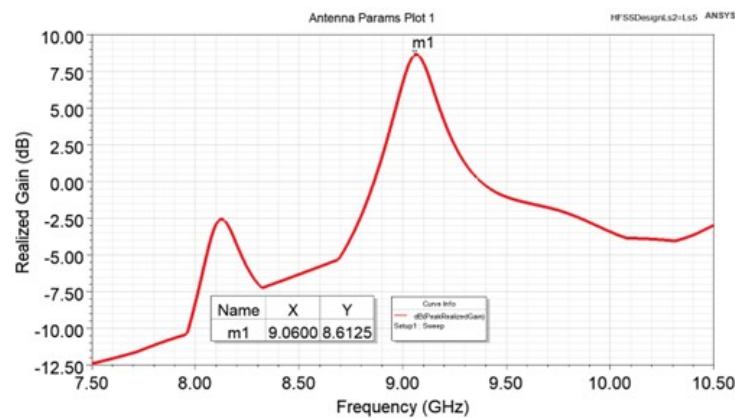


Figure 4.10: Gain plot of 2x2 array

since it directly impacts the antenna’s capacity for signal transmission and reception. A filtering antenna’s radiation efficiency can be impacted by a number of variables, including the antenna’s design, operating frequency, and construction materials. To ensure that the majority of the input power is transformed into radiated power rather than being wasted through heat or other losses, a well-designed filtering antenna should have a high radiation efficiency, often better than 80 percent.

High radiation efficiency can be difficult to achieve, particularly in intricate antenna designs that contain filtering components. A filtering antenna’s design and construction, including the material choice, tuning of the antenna elements, and optimisation of the filtering circuits, must be carefully considered to guarantee high radiation efficiency. High radiation efficiency and ideal performance can also be ensured with proper testing and calibration of the antenna. Array has radiation efficiency of

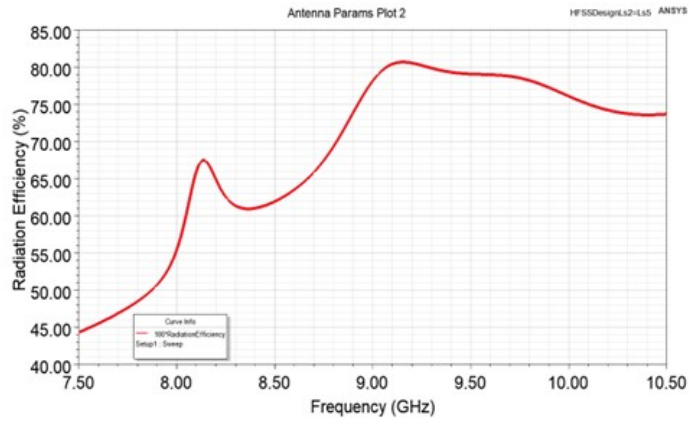


Figure 4.11: Radiation efficiency of 2x2 array

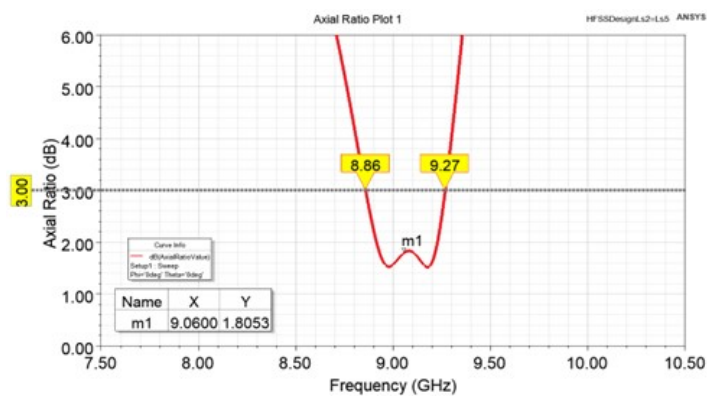


Figure 4.12: Axial ratio of 2x2 array

81percent which can be clearly seen in Figure 4.11 and axial ratio of 1.8dB which can be seen in 4.12. Therefore, antenna array exhibits high radiation efficiency and good axial ratio.

An antenna's axial ratio is a parameter that is frequently used to characterise its polarisation properties. It is described as the proportion of the minor axis to the major axis of the electromagnetic wave that the antenna is radiating. The axial ratio, put simply, expresses how elliptical the polarisation of a signal transmitted by an antenna is. The axial ratio of a fully circularly polarised antenna would be approx 1.

Chapter 5

Conclusion and Future Scope

Due to the advantages of low profile, lightweight, compact size, and ease of integrating lumped components (active or passive), MA has replaced the traditional reflector and wire antennas in wireless mobile communication, satellite, and radar systems. Despite the advantages mentioned above, the conventional MA has problems because of its narrow BW and low gain. Printing the patch on a thicker dielectric increases the impedance BW of the MA, but the technique also introduces undesired surface waves from the feed. Because of the intricately formed resonators, these antennas can only operate in a single band, and their geometry is quite complicated. Multiway power dividers are complex to design, which is an issue. Large distances separate output ports, which restricts array applicability. In the array antenna design, mostly microstrip line based inset feeding is used for the antenna element. But in this work aperture coupling technique has been incorporated to obtain good polarization purity. Also, it is challenging to design the array for dual resonances. In planar MA, multiple patches of varying sizes are stacked, the high order modes are excited, the patch is loaded with two narrow rectangular slots close to the radiating edges, the metamaterial resonator or complementary split ring resonator is placed in the patch or ground plane, and finally, the multiple resonances are obtained. The C band frequency range is the only one where it operates, and cross polarisation is highly high.

A new dual band high gain ACA array has been presented. The dual frequency resonances are achieved by incorporating an asymmetric H-shaped slot as the coupling aperture. The operating principle of the dual band ACA is explained using a detailed

parametric variation and surface current distribution. The basic antenna prototype resonates at 8.45 and 11.15 GHz. The 16 elements of the dual band ACA are arranged in 2D matrix by designing an equal power division corporate feed network. The potential application for the designed dual band array can be X-band weather radar and satellite communication system.

Radar systems, satellite communication, and wireless communication systems all make extensive use of phased array antenna systems. Power dividers are essential in these systems for distributing power among the antenna elements. To enhance the system's overall performance, power dividers can be used with other parts including amplifiers, filters, and switches. Dual band 4x4 ACA can be integrated with phase shifters to create phased array antenna systems and filtering can also be provided to modified as filtering 4x4 ACA. Phased array antenna systems that can function at higher frequencies will be necessary for 5G and beyond. For the development of such systems, power dividers that can function at these higher frequencies would be essential.

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