Design, Analyse and Improvement the Gain and Efficiency of Feed Horn Antenna by using Microstrip Array Feed.

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Abstract: **The characteristic of microstrip array antenna is narrowband. Wide-beam antenna fabricate by etching the antenna element pattern in metal trace bond to an insulating dielectric substrate, such as a printed circuit board (PCB), with a continuous metal layer bond to the opposite side of the substrate which forms a ground plane. The niche point in this research is the array arrangement and configurations of microstrip antenna. This characteristic will translate result in terms of high gain, wide bandwidth and improve efficiency.**

Keyword list – Microstrip Antenna, Array Antenna, Array Feed, Reflector Antenna, Off-set parabolic Reflector

I. INTRODUCTION

This research is more focus on the employ of an array antenna in order to increase antenna gain efficiency on the feed horn. As we know that an array antenna pattern is a wide-beam, narrowband and it's fabricated by antenna element design in metal trace bonded to an insulating dielectric substrate, such as a printed circuit board (PCB), with a continuous metal layer bonded to the opposite side of the substrate which forms a ground plane. The rationale of this research is to get the radiation pattern of the feed antenna and measure or compare with the previous results show that there are improvement in term of gain and efficiency. It has to be tailored to the design of the microstrip array as feed point, because it has a strong influence on the aperture efficiency, which determines the antenna gain. To analyse the radiation pattern synthesis, the method is based on the least mean square concept is employed. With this concept, the array excitation phases and amplitudes for the high antenna gain are determined [1]. The reflector antenna must operate in the dual frequency bands corresponding to up links (transmit) and down links (receive) of a satellite communication. The radiation pattern and characteristics of the microstrip antenna in the dual frequency bands are ensure through CST Studio Suite software simulations.

a. Background of the research

Nowadays, the modern wireless communication system specifically in satellite communication systems requires light weight, high gain, and simple structure antenna to assure mobility, reliability and high efficiency characteristic. Microstrip array antenna satisfies such requirements. The keys features of a microstrip array antenna are easy to fabricate, low cost, light weight also conformability to the mounting surface or, an extremely thin layer from the surface. This antenna provides all the advantages of printed circuit technology and makes them popular in many wireless communications application such as satellite communication, radar and medical applications. Microstrip array antenna also have an easy-to-install features for spacecraft application, and the capability to do beam-shaping due to its simple structure which is the precise contour beam depends on its accuracy design. In this research, an array feed is employed in order to increase antenna gain and efficiency by synthesizing the array feed radiation pattern to archive a constant aperture illumination on the offset parabolic reflector and the high antenna gain. Thus, the efficiency of the antenna can be increased.

b. Research Objectives

The objectives of this research are;

I. To design an array feed microstrip antenna using CST Studio Suite simulation software,

II. To fabricate, analyse and evaluate the array feed antenna configurations and compare with previous measurement result,

III. To verify that using array feed antenna as a feed horn of an offset parabolic reflector, the efficiency and gain antenna shows improvement.

c. Methodology of the research

As a simple parabolic reflector antenna, the high gain design of an offset parabolic reflector by an array feed was identified and important technical results are as follows.

(1) Radiation pattern synthesis method of an array feed,

(2) Feed radiation pattern for the uniform aperture distribution,

(3) Design of dual frequency array feed,

(4) To ensure an array radiation patterns, antenna aperture distributions and antenna radiation patterns through electromagnetic simulations,

(5) To ensure high aperture efficiencies are through simulated results,

There are 4 stages in this research to design a microstrip antenna which will function at range 7GHz until 18 Ghz using CST Studio Suite software. Designing the microstrip array antenna will be the main focus for this research to achieve required results. The whole process for this research is translated in Fig 1 as follows;

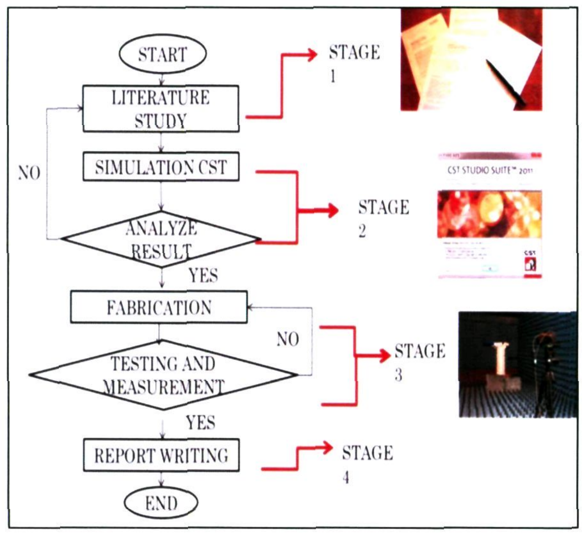

Fig 1: Design Stages

II. DESIGN OF ARRAY FEED

Different arrangement of array configurations of microstrip antenna can produce high gain, wide bandwidth and improved efficiency. The distribution of voltages among the elements of an array depends on feeding network. Suitable feeding network accumulates all of the induced voltages to feed into one point [2]. The proper impedance matching throughout the corporate feeding array configurations, provides high efficiency of the microstrip antenna[3]. Power distribution among antenna elements can be modified by corporate feed network. The corporate feed network can steer beam by introducing phase change[4]. The design of parameters (dielectric material, height and frequency, etc) is important because antenna performance depends on these parameters. Radiation performance can be improved by using proper design structures [5]. The use of high permittivity substrates can miniaturize microstrip antenna size[6]. Thick substrates with lower range of dielectric offer better efficiency, and wide bandwidth but it requires larger element size[7]. Fig. 2 shows the antenna configuration with the array excitation coefficients for a shaped beam. The offset parabolic reflector is fed by an array feed. [8]

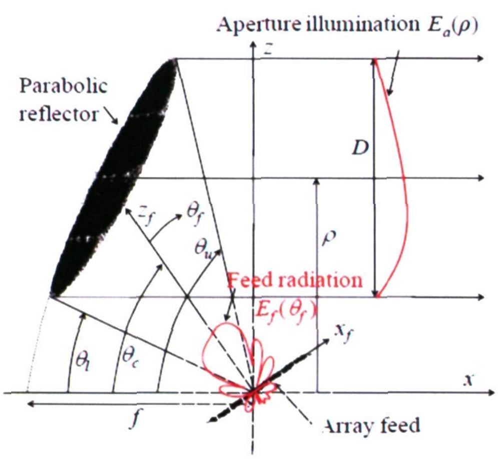

Fig 2: Antenna Configuration

The antenna aperture illumination Ea(p) is determined from the simple relation to the radiation pattern Ef (f) of the array feed as follows,

$$Ea(p)=\frac{1}{2} f\ Ef(\theta)cos^2\left(\frac{\theta}{2}\right) \qquad (1)$$

For achieving uniform illumination on the aperture plane, Ef (θf) must satisfy the following expression,

$$Ef(\ f) = \frac{2f}{\cos^2\left(\frac{\theta}{2}\right)} \qquad (2)$$

The shape of Ef (θf) given by equation (2) is shown in Fig 2. The strengths are normalized by the value at the angle θu. The required Ef (θf) has the shape of a slope. This shape is quite different from those of the ordinal radiators.

The position of the array element during designing based on the Table 1 below:

Beam Point	Coordinate relative to *0*		Feed position (m)		
	AZ(0)	EL(0)	Δ x	Δ y	Δ z
1	-0.8 °	-0.30°	0.064	0.001	0.025
2	-0.8°	-0.80°	0.064	0.001	0.064
3	-1.3°	-0.50°	0.102	0.002	0.043
4	-1.4°	0.10°	0.115	0.003	-0.010
5	0.18°	-0.70°	-0.017	0.001	0.058
6	0.93°	-0.70°	-0.083	0.001	0.058
7	1.6°	0.11°	-0.106	0.004	0.015
8	1.3°	-.18°	-0.075	0.002	-0.018

Table 1: Feed position

From the input in Table 1, feed position can be derived via Mathlab software which is the result for ray tracing of the offset feed parabolic reflector antenna. Table 2 shows the Mathlab parameter,

Item	Details/Value	Description
Common Parameter	freq = 12.2;% frequency [GHz]	Reference Frequency
	lamda = 0.3/freq;	Wave length [m]
	ak = 2*pi/lamda;	Wave number
Reflector parameters		
	f = 4.5;%	Focal legth [m]
	thetam = 19*pi/180;	Angle to reflector rim [rad]
	rhom = 2*f/(1+cos(thetam));	Distance to reflector rim
	zap = (rhom*sin(thetam))^2/(4*f)-f;	Position of aperture plane [m]
	Dap = 3	Aperture diameter [m]
Array feed position (Based on table 1.1)	fx = 0.0;	x component [m]
	fy = 0.0;	y component [m]
	fz = 0.0;	z component [m]

Table 2: Mathlab parameter

The result from Mathlab simulation, relative radiation pattern on each beam point was measured and the reflector plane, aperture plane and aperture phase distribution results shows in Fig 3.

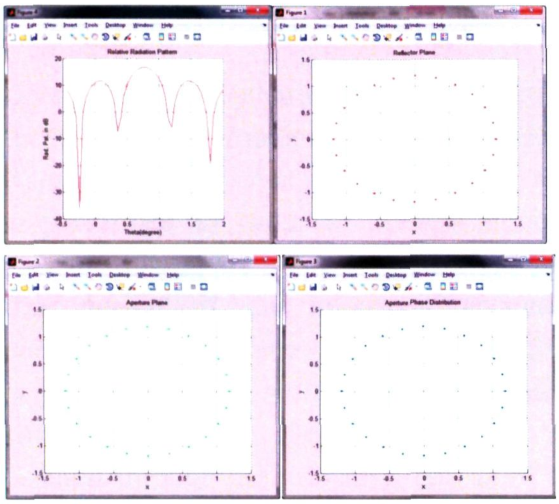

Fig 3:Mathlab Simulation Results

III. CHARACTERISTIC OF THE FABRICATES ANTENNA

The design of an array antenna based on equations shows in Fig 4, which is the ideal measuring to get width, *W* and length, *L* for single patch as a reference for another array to be fabricated.

$$w = \frac{1}{2f_r\sqrt{\mu_o\varepsilon_o}}\sqrt{\frac{2}{\varepsilon_r+1}} \quad (1)$$

$$l = \frac{1}{2f_r\sqrt{\varepsilon_{reff}}\sqrt{\mu_o\varepsilon_o}} - 2\Delta L \quad (2)$$

Where

$$\Delta L = \frac{0.412}{h}\frac{(\varepsilon_{reff}-0.3)(\frac{W}{h}+0.264)}{(\varepsilon_{reff}-0.258)(\frac{W}{h}-0.8)} \quad (3)$$

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{W}\right]^{-1/2} \quad (4)$$

Fig 4: Equation for Width and Length of the patch array.

In this research, the designated frequency or reference frequency, *fr* is 12.2 GHz using FR-4 substrate with 1.6mm thickness and substrate permittivity, ϵ=4.3. From the equation in Fig 4, the measuring of the patch summarize as simulation parameter as Table 3.

Item	***Parameter***	***Details/Value***	***Description***
General			
	Substrate	FR-4	
	h	1.6 mm	Substrate thickness
	Eps r	4.3	Substrate permittivity
	Tan δ	0.0018	
	Z0	50 Ohm	System characteristic impedance
	Hertz	5~13	Frequency range
	Fr	12.2	Frequency reference
Dimension of patch			
	W	7.550 mm	Width
	L	6.547 mm	Length
	Lf	0.736 mm	Length of feedline
	Wf	0.786 mm	Width of feedline
	t	0.035 mm	Metallization thickness (cooper)

Table 3: Simulation Parameter

From a calculated single patch, the design was calculated based result position by Mathlab also consider impedance Z_p=50Ω with Z_1=35Ω for matching feed and the final design for this research shows in Fig 5,

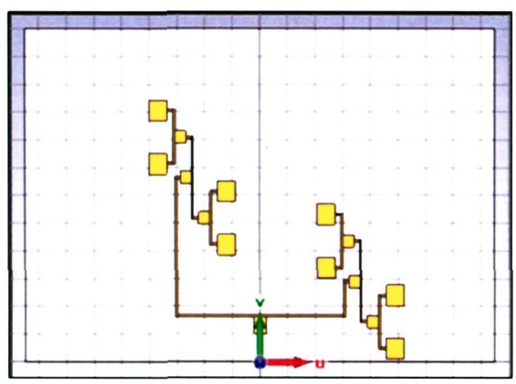

Fig 5: Simulation Design

IV. SIMULATION RESULTS

Detailed radiation characteristics are clarified through electromagnetic simulations. Radiation pattern synthesis of an array feed is performed in order to achieve uniform aperture illumination for the offset antenna. The design of the important excitation coefficients of the array feed is successfully performed through accurate electromagnetic simulations. The design accuracies are ensured through the measured results of the fabricated array feed. Moreover, the antenna radiation characteristics are obtained by combining the array feed with a parabolic reflector..

The 3-D radiation patterns of the array feeds are shown in fig 6, shows that gain archive G= 9.92 dbi

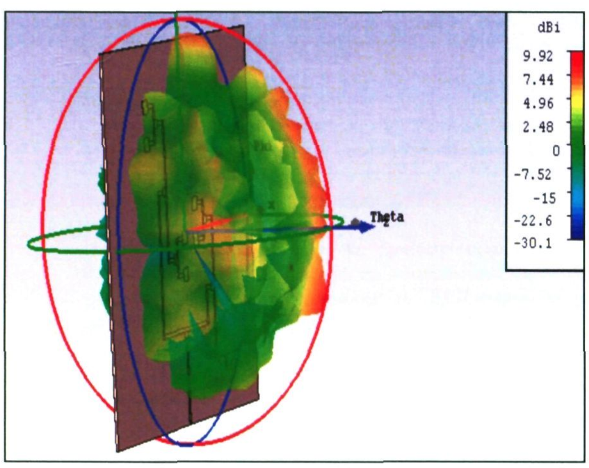

Fig 6: Farfield Pattern

S1.1 graph in fig 8 shows that the dual frequencies generated in order to translate the received and transmit radiation if the designed microstrip antenna with 7.5Ghz and 16.8Ghz repectively.

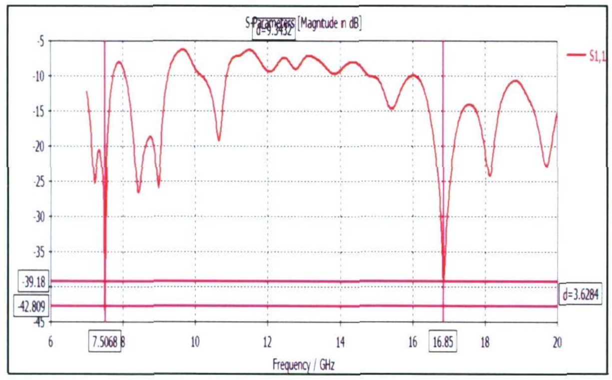

Fig 8: S1.1 Parameter

Simulated radiation patterns in the dual frequency bands are shown in Fig. 8. It is understood that radiation patterns are well shaped similar to the shape of Fig.5 and radiation patterns agree very well in the dual frequency bands.

The directivity of the designed microstrip antenna in Fig 7 shows that radiation patterns of the offset parabolic reflector are shown in figure 9. The =90 degree corresponds to the antenna front. Excluding the spillover area, very low sidelobe characteristics are achieved

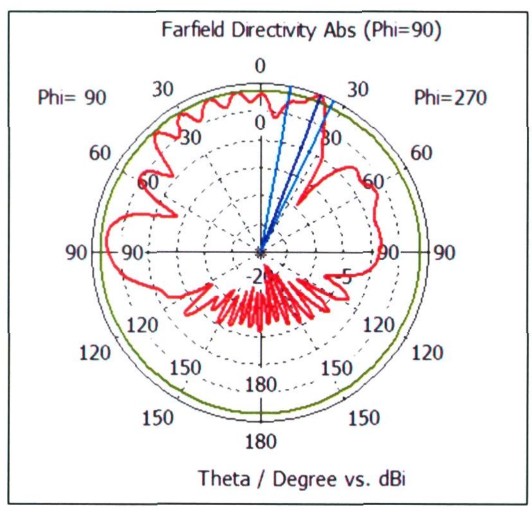

Fig 7: Farfield Directivity

V. CONCLUSION

To design a simple, light weight and portable earth station antenna, an array feed is studied to to get the high gain of an offset parabolic reflector antenna.

The vital technical results from the simulation are as as follows:

1. Antenna aperture distributions, array and antenna radiation patterns are ensured through electromagnetic simulation.

2. Synthesis of the radiation patterns method of an array feed is clarified

3. Feed radiation patern for the uniform aperature distribution is obtained.

4. Dual frequencies array feed is designed

5. High gain and aperture efficiencies are ensured through simulated results.

VI. REFERENCE

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