Enhancement of Gain of Aperture-Coupled Microstrip Antennas Using Composite Materials

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***Abstract*— This paper presents the effect of low permittivity materials used as a superstrate layer for enhancing the gain of the microstrip antenna. The design and development of two-element equilateral triangular microstrip array antenna is proposed in this study. Polyester composite materials are used as superstrate material in the present study. The radiating patches are fabricated on the thin sheets made of polyester, polyester fly ash and polyester ferrite composite materials. The patches are fed using corporate feed technique through slots. The feed arrangement is etched on glass-epoxy substrate underneath the ground plane. The slots are kept at the top of feed line and etched on the opposite side of the feed network. The measurements were carried out at X-band frequencies. From the experimental results it is observed that, the HPBW and gain of the MSA can be improved considerably using composite material superstrate when compared to conventional microstrip patch antenna. This shows the superiority of composite materials in enhancing the gain of microstrip antenna.**

***Keywords*— Composite materials, corporate feeding, aperture-coupled feeding, SMA connectors, Superstrate material**

I. Introduction

Now a days developments in wireless communications often require antennas with compact size, low cost and more efficiency. Owing to its thin profile, light weight, low cost and easy fabrication, the microstrip antennas (MSAs) are suitable for these requirements. The response of MSAs depends on the material used for their fabrication in the photolithography process.1

There are many fascinating areas of research related to the response of materials. The role of the material as a dielectric substrate which is used to design a microstrip antenna (MSA) is very important. MSAs are widely used in a broad range of commercial and military applications mainly because of their advantageous features in terms of low profile, low cost, light weight and easy manufacturability. However, two major disadvantages associated with MSAs are low gain and narrow bandwidth.2

It is well known that a multilayer structure is a useful method to improve these problems 1, 3. Most works have been done in improving the bandwidth but little in enhancing the antenna gain. However, the multilayer MSA has particular characteristics such as a high gain or a wide bandwidth.

In this paper, we proposed a new design concept of equilateral triangular microstrip patch antenna using low cost, low permittivity composite material as superstrate material. The radiating patches are deposited on the underside of thin superstrate materials made of polyester (PE), polyester-fly ash (PFA) composite and polyester-ferrite (PF) composites. The feed arrangement is etched on glass-epoxy (GE) substrate underneath the ground plane. The slots are kept at the top of feed line and etched on the opposite side of the feed network. It is found that, by using the composite material superstrate for radiating patches, an enhanced gain and HPBW for the proposed design is observed.

II. Description of Antenna Geometry

Fig. 1 shows the geometry of two-element equilateral triangular microstrip array antenna (TETMAA).

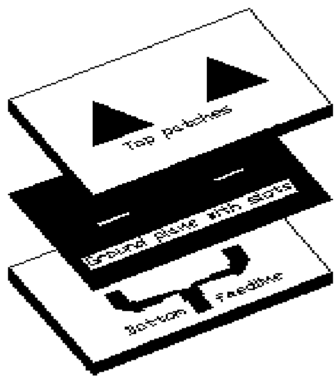

Fig. 1 Antenna Geometry of TETMA

The two radiating patches shown in this figure are kept at a distance of $3\lambda_0/4$ in order to add the radiated power in free space by individual element4. The corporate feed technique is used to drive the patches. This technique has been selected because of its simplicity in fabrication. The corporate feed arrangement consists of quarter wave transformer, matching transformer, power dividers and microstrip bend for better impedance matching. The SMA connector is used at the tip of 50 Ω feed line for feeding the microwave power. The radiating elements of TETMAA are fed by slots through aperture coupled feeding technique1. The length and width of the slot in the feed arrangement is selected as $\lambda_0/5$ and $\lambda_0/32$ respectively, where λ_0 is the free space wavelength in cm.

The superstrate material on which the radiating patches (as shown in the Fig.1) is etched on different polyester composite materials (PE, PFA, PF). The PFA & PF composite sheets were prepared by the conventional mould techniques by taking 5% by weight of the sintered fly ash and ferrite powders and mixing it with polyester resin matrix. Dielectric constant of PFA & PF samples were measured and are found to vary from 1.9 to 1.2 for PFA samples and 1.7 to 1.1 for PF samples respectively at X-band frequencies. The computer software Auto-CAD is used to achieve better accuracy in designing of these antennas. The antennas are fabricated using photolithography process.

III. EXPERIMENTAL RESULTS

The gain of TETMA is measured at resonating frequency 11.94 GHz by knowing the power transmitted (PT) by the pyramidal horn antenna and received power (PS) by the TETMA. Using these data the gain (GT) of TETMA in dB is calculated by using the formula

$$(G_T)_{dB} = (G_S)_{dB} + 10 \log \left(\frac{P_T}{P_S} \right) \qquad (1)$$

The value of $(G_S)_{dB}$ is calculated by using the equation

$$(G_S)_{dB} = 10 \log \left(\frac{2\pi ab}{\lambda^2} \right) \qquad (2)$$

where, a and b are the broader and narrow wall dimensions of pyramidal horn antenna respectively in cm. The gain of TETMAA with PE, PFA and PF as superstrate measured separately. These values are given in Table 1.

TABLE I
GAIN MEASURED AT RESONATING FREQUENCY 11.94 GHZ

Sl. No.	Antenna gain with various superstrate materials		
	Antennas	**Gain indB**	**Superstrate material**
1	TETMAA	-1.98	Conventional antenna with glass epoxy (GE)
2	TETMAA with PE composite as superstrate	1.86	Superstrate material is polyester (PE)
3	TETMAA with PFA composite as superstrate	2.15	Superstrate material is polyester-fly ash (PFA)
4	TETMAA with PF composite as superstrate	-0.22	Superstrate material is polyester-ferrite (PF)

From Table 1 it is seen that the use of PE as superstrate increases the gain of TETMAA by 3.84 times, PFA increases 4.13 times and PF increases 1.76 times when compared to the gain of conventional TETMAA with glass epoxy as superstrate material.

Fig. 2 shows the H-plane radiation pattern plotted between normalized power versus azimuth angle of TETMAA measured at 11.94 GHz. The H-plane radiation pattern of TETMAA with superstrate materials such as PE, PFA and PF measured at same frequency is also shown in Fig. 2 for the sake of comparison. From this graph the half power beam width (HPBW) is calculated. The obtained values of HPBW are given in Table 2. From this table it is clear that the HPBW of TETMAA decreases with the use of superstrate materials. In other words the directivity of antenna increases as the beam is sharpened which is evident from following Fig. 2.

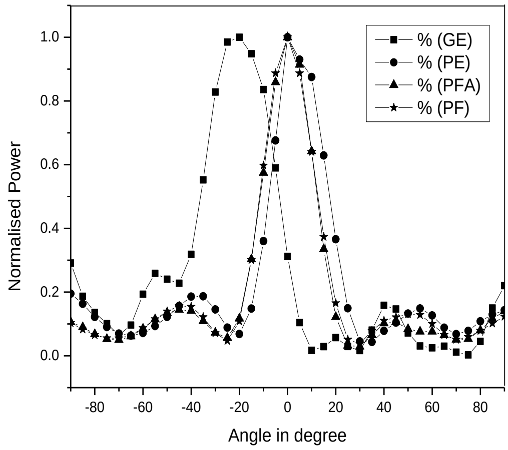

Fig.2 H-plane radiation patterns at resonating frequency 11.94 GHz

From the Fig. 2 it is clear that, using composite materials as superstrate for TETMAA, the gain of proposed antenna enhances with the sharpening of the HPBW. The reduced HPBW makes the antenna to give more gain which is clear from Table 2. From the table 2 it is very clear that, the sharpening of the beam is 55% more when the superstrate material is PE with respect to conventional superstrate GE. Similarly, the sharpening of HPBW is 60% when the superstrate materials are PFA and PF with respect to GE material.

TABLE II
HPBW MEASURED AT RESONATING FREQUENCY 11.94 GHZ

Sl. No.	HPBW of proposed antennas		
	Antennas	**HPBW in degree**	**% of sharpening**
1	TETMAA	40	-(Conventional antenna)
2	TETMAA with PE	18	55
3	TETMAA with PFA	16	60
4	TETMAA with PF	16	60

IV. CONCLUSIONS

The The present study successfully shows that, gain of MSAs can be enhanced by using composite materials as a superstrate material in multilayer aperture-coupled feeding technique. From the detailed experimental study it is found that, the proposed antenna TETMAA is quite capable of enhancing the gain and sharpening the beam when polyester composite materials are used as superstrate materials when compared to GE material.

The detailed experimental study of TETMAA with PE superstrate increases the gain by 3.84 times, with PFA superstrate 4.13 times and with PF superstrate 1.76 times when compared to the conventional superstrate GE material. Also, with composite materials as superstrate material for antenna fabrication, the sharpening of the HPBW of proposed antennas is increased upto 55% and 60% more when compared to the conventional GE superstrate material. This shows the superiority of polyester composite materials over GE material in enhancing the gain and directivity of microstrip antennas. Such antennas are very useful in radar and wireless communications.

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