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SUPERSTRATE EFFECTS ON IMPEDANCE AND RADIATION CHARACTERISTICS OF MICROSTRIP ANTENNAS

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INTRODUCTION – In many applications, microstrip antennas are covered with dielectric superstrates to provide protection against climatic and environmental hazards. Dielectric superstrates may affect seriously antenna performance such as the resonant frequency, input impedance, radiation patterns and gain, etc. Bahl et al [1] described simple calculations and experimental results for the fractional change in the resonant frequency resulting from the superstrate. Jackson and Alexopoulos [2] presented a full-wave analysis with calculated radiation patterns for a printed dipole embedded in a two-layer dielectric. They indicated from the theoretical study that the gain enhancement may be realized by choosing the superstrate thickness and the dipole position properly. Lin and Zhong et al [3] reported experimental results for the gain enhancement by simply covering a superstrate with proper spacing to the radiating elements of common microstrip antennas. Hansen and Patzold [4] applied the moment method to solve the integral equation in spectral domain for covered patch antenna, and gave some computed input impedance loci of a patch element covered by a layer of ice. Bhattacharyya and Tralman [5] studied experimentally resonant frequencies of rectangular patches for various thickness of the cover. Benalla and Gupta [6] reported an analysis by the extension of multiport network model for covered rectangular patches, and presented the computed and measured results of the input reflection and the resonant frequency. Recently, our group [7-9] has done some analysis on radiation patterns, gain and resonant frequency for the covered patches by means of the Green's function method and the integral equation method. It is noted that none of the above works provide the detailed measured results of the impedance loci and radiation patterns for the covered patches. The purpose of this communication is to present these measured results not only for the cases with one layer of cover but also for a case with two-layer cover from which some useful informations are achieved.

EXPERIMENT– The geometerical structure under consideration is shown in Fig. 1. A rectangular patch of dimension 46.35 mm x 30.45 mm on 4 mm thick substrate with dielectric constant 2.75 was fabricated. The patch was fed through probe of 50 Ω cable. The location of feed probe had been found theoretically and chosen as $x = 0$, $y = 5.3$ mm. Then the patch was covered with different thickness of PTFE ($\varepsilon_r = 2.1$), Glass ($\varepsilon_r > 4$), and PTFE and Glass together. The impedance characteristics were measured by means of HP 8510B network analyser. The radiation pattern measurements were performed in the anechoic chamber by the use of automatic antenna analyser.

RESULTS AND DISCUSSION– The measured impedance loci with frequency range of 2 GHz to 3 GHz are shown in Fig. 2, with seven cases, where " x " for each case indicates the point of the lowest VSWR. At this point, its input impedance, VSWR and the fractional bandwidth of VSWR ⩽ 2, etc. are listed in Table 1, where the frequency of this point is defined as the resonant frequency f_r .It can be seen that this frequency approaches to the frequency of zero input reactance for cases 1 and 2.

TABLE 1 MEASURED IMPEDANCE CHARACTERISTICS

No	Cover	Thickness (mm)	f_r (GHz)	$\Delta f_r / f_r$ (%)	Z_{in} (Ω)	VSWR	BW (%)
1	No	0.0	2.73	0.00	45.87+j5.06	1.146	5.16
2	PTFE	2.2	2.70	1.28	47.31+j1.99	1.071	5.52
3	PTFE	6.1	2.665	2.38	52.58-j3.87	1.095	5.84
4	PTFE+GLASS	2.2+2.6	2.575	5.68	62.77-j22.48	1.580	5.42
5	Glass	2.6	2.55	6.59	57.19-j8.90	1.238	5.52
6	Glass	4.9	2.44	10.62	70.59-j27.22	1.763	3.28

From Table 1, it is observed that the resonant frequency f_r decreases monotonically with the increase in the superstrate thickness and the dielectric constant of the superstrate. Actually the latter (ε_r) is more sensitive to affect f_r . For instance, for PTFE Superstrate of thickness 6.1 mm (case 3) f_r decreases by 2.38 % , whereas for glass sheet of thickness 2.6 mm (case 5) f_r drastically decreases by 6.59 % .It is significant to note that for the case 4 with 2.2 mm thick PTFE laminate between the glass sheet of 2.6 mm thickness and the patch, its frequency decrease is less than that of the case 5 with an only glass cover of 2.6 mm thickness. This implies that the frequency change can be weakened by the presence of a spacing layer with lower ε_r between the high ε_r cover and the radiating element.

The general trend of impedance characteristics is that both the input resistance and the capacitive reactance are increased as the superstrate becomes thick and its ε_r increases, whereas the bandwidth (VSWR ⩽ 2) has not notable change.

Fig. 3 shows the measured radiation patterns in the E- and H-planes for different dielectric superstrates.The measured 3 dB beamwidths of E- and H-planes for cases at various frequencies are listed in Table 2 and 3.

TABLE 2. MEASURED E-PLANE 3 dB BEAMWIDTHS

No.	Cover	Thickness (mm)	Frequency (GHz)					
			2.65	2.70	2.75	2.80	2.85	2.90
1	No	0.0		70.0	69.2	68.9		
2	PTFE	2.2	73.7	74.9	75.3	75.7	75.7	75.2
3	PTFE	6.1	73.0	74.1	73.9	74.1	73.9	74.3
4	PTFE+Glass	2.2+2.6	68.6	68.0	67.4	67.4	67.3	67.5
5	Glass	2.6	70.2	70.5	70.1	69.1	67.6	68.7
6	Glass	4.9	65.1	64.3	63.9	63.8	63.2	64.1

TABLE 3. MEASURED H-PLANE 3 dB BEAMWIDTHS

No.	Cover	Thickness (mm)	Frequency (GHz)					
			2.65	2.70	2.75	2.80	2.85	2.90
1	No	0.0	67.8	66.3	67.5	68.2	67.4	64.6
2	PTFE	2.2	72.1	69.7	70.6	71.4	71.0	68.0
3	PTFE	6.1	71.7	69.9	72.3	72.6	70.3	65.9
4	PTFE+Glass	2.2+2.6	65.9	66.0	66.7	66.3	63.6	60.5
5	Glass	2.6		59.9	63.3	64.2	61.3	58.1
6	Glass	4.9	62.9	63.2	62.4	60.7	58.0	57.3

It is observed that the radiation patterns are changed for different covers, especially in the sidelobe range. The 3 dB beamwidths become narrower or wider depending upon the dielectric constant and thickness of the superstrate. Of most interest is that both the E- and H- 3 dB beamwidths are reduced for the 4.9 mm thick Glass cover (case 6) and the PTFE plus Glass cover (case 4), resulting the probable gain enhancement. Therefore, the gain can be optimized by proper cover structure - proper thickness of each layer and its dielectric constant.

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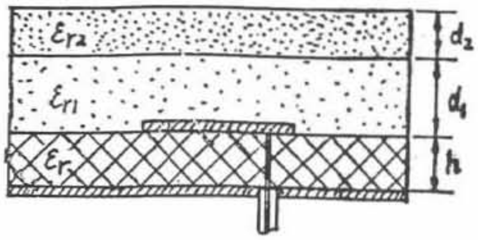

Fig. 1 Geometry of dielectric covered patch

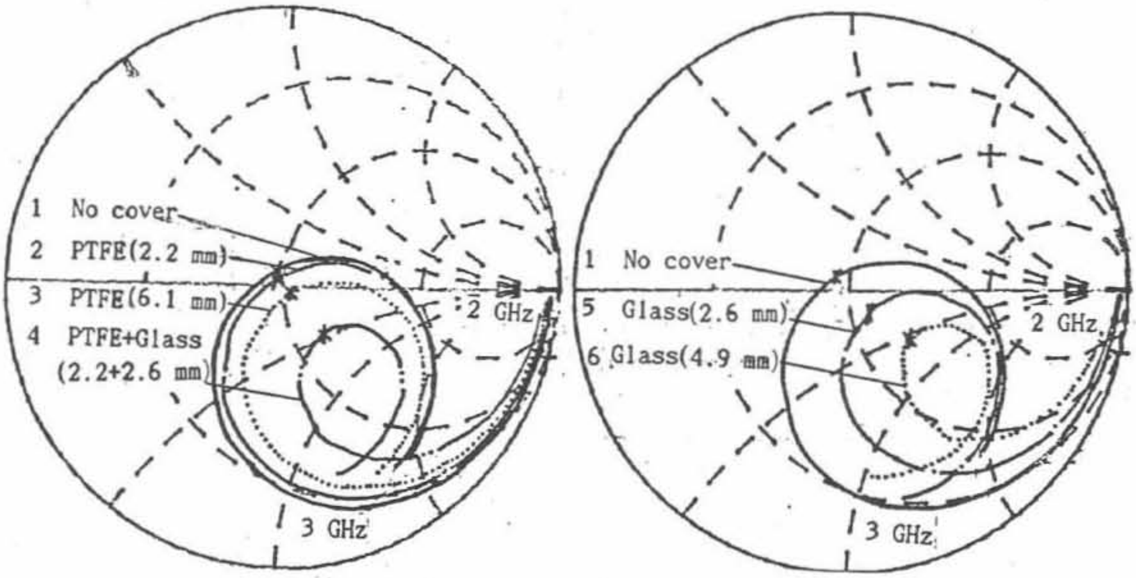

Fig. 2 Measured impedance loci

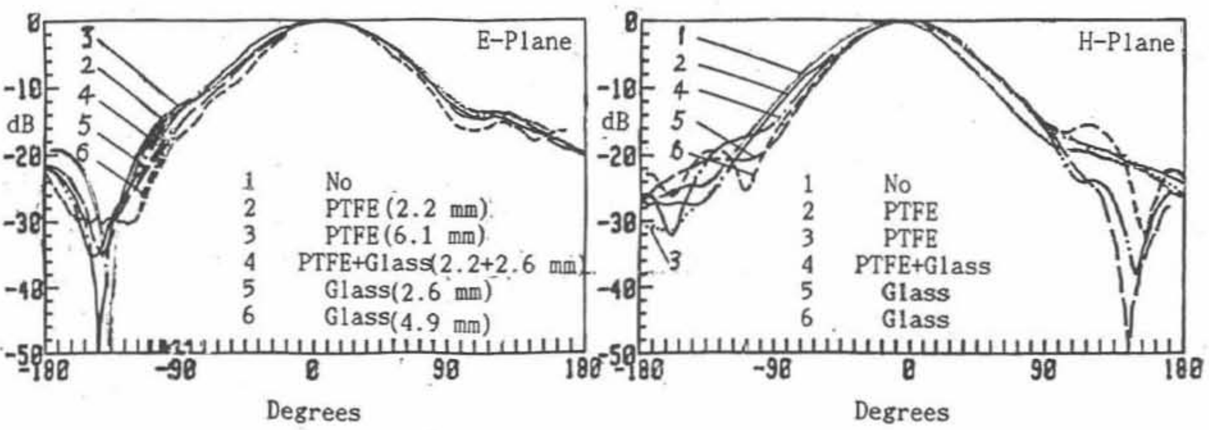

Fig. 3 Radiation Patterns in the E-and H-Plane