STACKED MICROSTRIP ANTENNA OPERATING IN TM_{01} MODE WITH A SINGLE FEED LINE

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1. Introduction

Microstrip antennas are small and low-profiled, light in weight and strong in structure [(1),(2)]. They have also advantages of easy manufacturing and low cost, and a disadvantage of narrow frequency band. Those advantages are beneficial to airplanes, rockets and other space vehicles.

The patch antenna operating in TM_{01} mode has been proposed which has a shorting post near a feed line [(3)]. The configuration is revised to include a center pole of thick conductor and a dielectric ring supporter in the periphery for the purpose of the excitation of TM_{01} mode and strengthening [(4)]. In order to have two operating frequencies, a stack of two patches with different frequencies has been proposed, together with a novel feeding scheme using only one coaxial cable [(5)]. This configuration is advantageous to simplify the structure and strengthen the antenna. On the other hand, two patches are strongly coupled through the center conductor of a coaxial cable and a hole so that the designs for two patches can not be clearly separated. In this paper the characteristics dependence on antenna parameters are experimentally studied.

2. Antenna Configuration and Features

A microstrip antenna of a single layer has a conductor pole at the center and dielectric ring at the periphery. This configuration is robust against vibration and thermal effects. The antenna operates in TM_{01} mode which has magnetic and electric fields in circumferential and thickness directions, respectively.

A microstrip antenna of double layers is shown in Fig.1. The smaller antenna is stacked on the larger one in order to have two frequencies resonance. The antenna is fed by a single coaxial cable. The upper antenna is excited by the current on the center conductor of the coaxial cable, while the lower antenna is excited by capacitive coupling between the coax center conductor and the patch in addition to the current.

This research is pursued to experimentally determine the design parameters to realize the desired characteristics with the objective frequencies at 2.10 and 2.30 GHz.

3. Impedance characteristics

The impedance characteristics of the antenna under test are measured with a network analyzer (HP8510A) and a synthesized sweeper (HP86640A) as shown in Fig.2. Double resonances are evident in Fig.3. The lower frequency corresponds roughly to the resonance of the larger antenna, while the higher frequency to that of the smaller antenna. In this case, the lower and higher resonance frequencies are both lower than the desired frequencies of 2.10 GHz and 2.30 GHz. The lower frequency resonance shows lower Q value than the higher frequency one. The coupling between two patch cavities affects more the lower resonance.

Return loss for various parameters is summarized for about 100 sample antennas with different parameters in Fig.4. The abscissa is the volume of the short-pole ($\pi b^2 h$) normalized by the total volume. The return loss decreases or increases with the volume ratio at the lower and higher resonance frequencies, respectively. But there is an exception in each resonance case which suggests the existence of other kinds of resonance.

The location of the feed line is indicated by the parameter ρ in both cases of (a) and (b), and is most influential. The loss can be reduced by locating the feed point closer to the center pole at the lower resonance, or farther from the center pole at the higher resonance, respectively.

The width of the dielectric ring supporter in the smaller patch (w_u) is discriminated by solid and dotted lines for two different values. The w_u is not so influential as the other parameters.

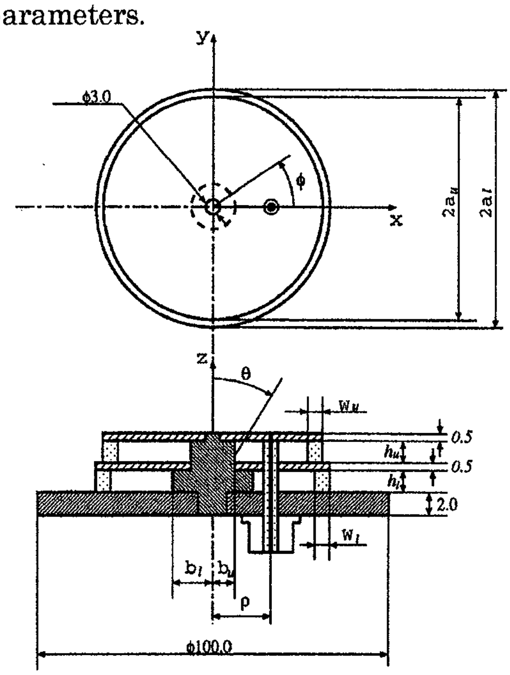


Fig.1. Configuration of the antenna under study.

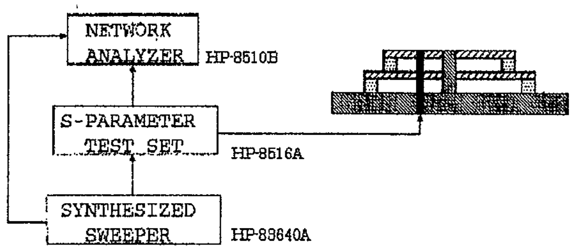
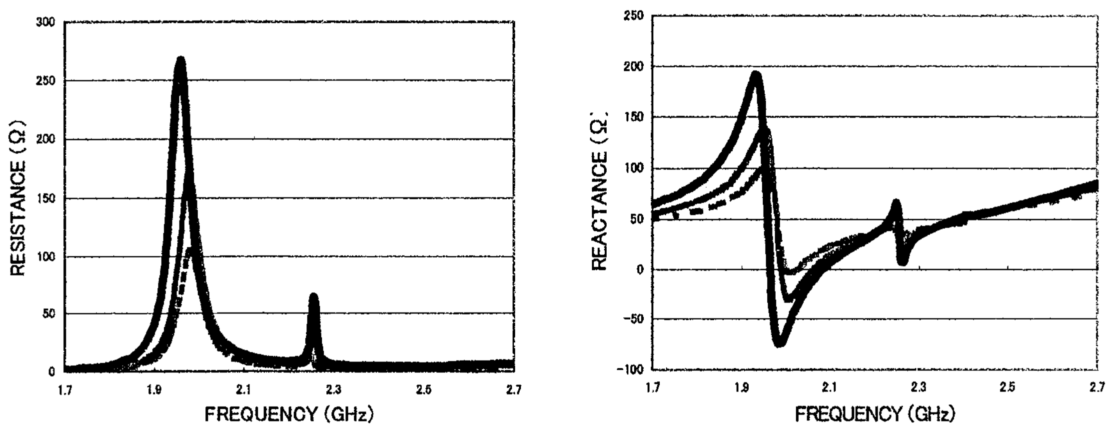


Fig.2. Impedance measuring system.



(a) Real part ···· ρ=6.0 – – ρ=7.0 —— ρ=8.0 (b) Imaginary part

$2a_u$=37.5mm, $2a_l$=41.2mm, $2b_u$=6.0mm, $2b_l$=8.0mm, w_u=10.0mm, w_l=5.0mm, h_u=h_l=1.5mm

Fig.3. Impedance versus frequency with various feed points.

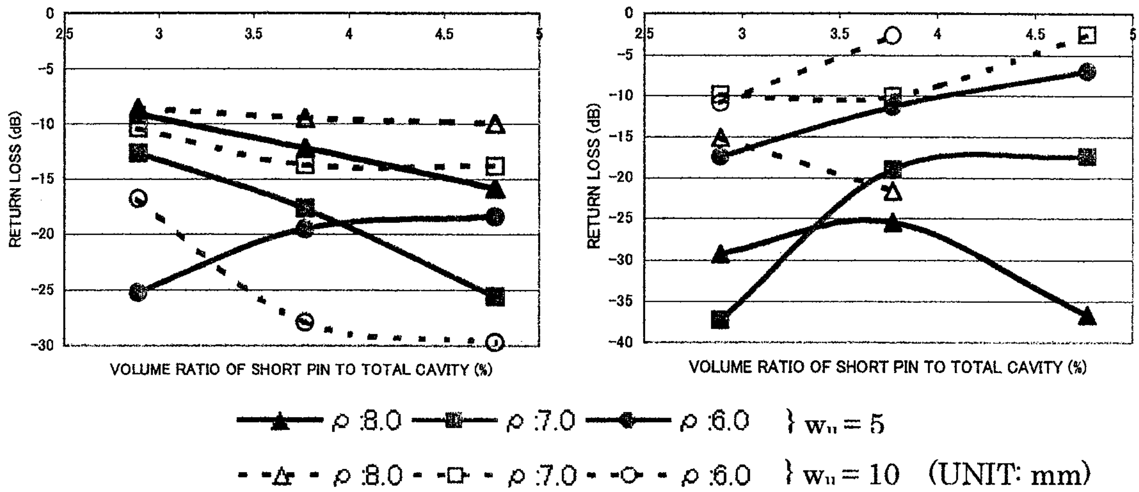
4. Resonance frequency

Figure 5 summarizes the measured results of resonance frequencies The resonance frequency increases almost proportional to the normalized volume of the pole in both cases of (a) and (b). Only one exception is the case of the higher frequency resonance with w_u =5 and with $\rho = 0.8$.

The resonance frequency is not affected much by the location of the feed line ρ, but changes more obviously at the higher resonance.

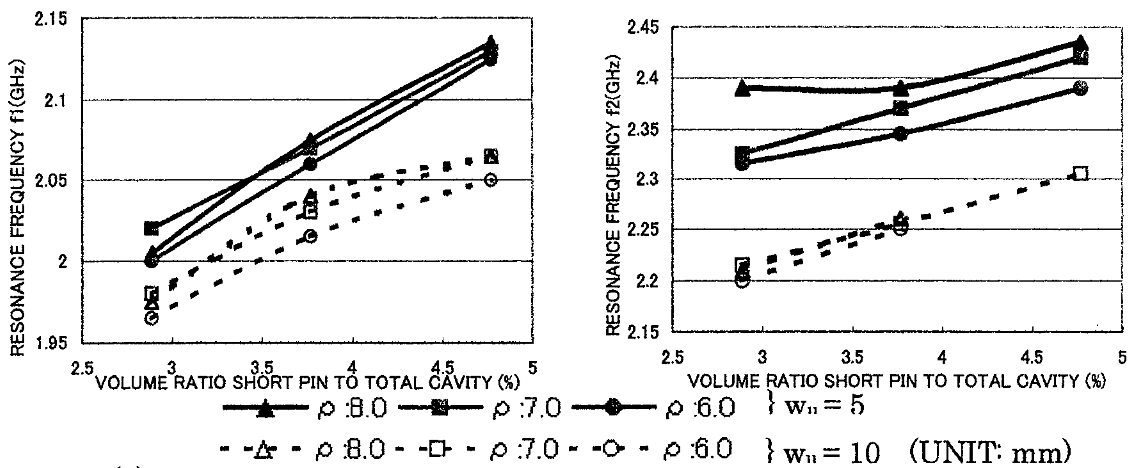
The higher resonance frequency is shifted lower with a wider supporter (larger w_u) which is inserted in the smaller patch, as expected. But the lower resonance is also affected by a small amount.

Frequency difference of two resonances becomes smaller with a larger volume ratio, and this tendency is more significant with a narrower dielectric supporter.



(a) Lower frequency resonance. (b) Higher frequency resonance.

Fig.4. Return loss dependence on structural parameters.



(a) Lower frequency resonance. (b) Higher frequency resonance.

Fig.5. Resonance frequency dependence on structural parameters.

5. Radiation patterns

The patch antenna of this configuration radiates a linearly polarized field with the null in the perpendicular direction to the patch. The radiation pattern is isotropic in the circumferential direction of the patch.

The measured patterns at lower resonance frequencies are shown in Fig.6 with different values of the patch height h. The patterns resemble a doughnut shape in three dimensions. With a larger value of h, the total radiated power or the radiation efficiency is improved. The antenna gain in the boresight direction is increased from 0 dBi to 4 dBi by enlarging the h from 1.5 mm to 3.0 mm.

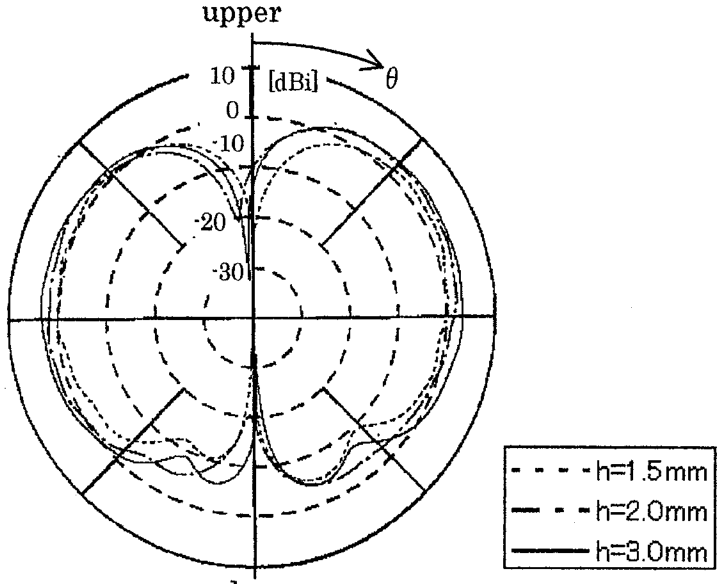


Fig.6. Measured radiation patterns. (E-plane)

6.Conclusions

(1) The larger patch which is located in the lower layer of the stack shows lower Q, and has the impedance more dependent on the antenna parameters.

(2) The resonance frequency is dependent on various parameters more significantly in the following order : the radius of the short pin > the width of the dielectric ring supporter > the location of the feed line.

(3) The dependence on the antenna parameters is not simple so that the double resonators with strong coupling through a hole and a wire should be solved, and the design should be finally verified by measurements.

(4) The following parameters of the antenna are obtained to realize the desirable characteristics at 2.1 and 2.3 GHz by measurements.

a_u=18. 75mm, a_l=20. 6mm, w_u=10. 0mm, w_l=5. 0mm,
b_u=3. 0mm, b_l=4. 0mm, h_u=h_l=1. 5mm, ρ =8. 0mm.

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