Evaluation of the Influence of Substrate Electrical Parameters over Matching of Microstrip Resonator

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Abstract – **Impedance matching of rectangular transmission line - fed microstrip patch is investigated in this paper. For evaluation of impedance matching the reflection coefficient (S_{11}) is used. On the basis of the variation of S_{11} the impedance bandwidth of the antenna can be defined. The varying of S_{11} is determined by the input impedance R_{in} of the antenna.**

Keywords – **microstrip antennas, antenna feeds, transmission lines.**

I. INTRODUCTION

Microstrip patch antennas are the most dynamic developing section of the antenna field in recent years. In communication systems the low weight, simple manufacturing, easy installation, aerodynamic profile and naturally low cost are important requirements to antennas. To a considerable degree the microstrip patch antennas meet those needs. They are inexpensive to manufacture, low-profile, conformable to planar and nonplanar surfaces, easy to produce using the widespread printed-circuit technology, mechanically robust. Major disadvantage of the microstrip antennas are their not very good electrical characteristics – low efficiency, poor polarization purity, low power, spurious feed radiation and narrow frequency bandwidth [1]. There are methods, such as increasing the height of the substrate, which can be used to increase the efficiency and the bandwidth [2].

The microstrip antenna consist of a very thin metallic strip (patch) ($t << \lambda_0$, where λ_0 is the free space wavelength), placed a small fraction of wavelength above a ground plane ($h << \lambda_0$). They are separated by a dielectric layer called substrate. The microstrip patch is designed so that its pattern maximum is perpendicular to the patch. This is achieved by proper choosing of the field configuration beneath the patch.

There are numerous dielectric materials that can be used for substrates in microstrip antennas and their dielectric constants are in the range of $2 \le \varepsilon_r \le 10$. Most desirable for antennas are thick substrates with dielectric constant in the lower part of the range because they provide higher efficiency, wider bandwidth, but also larger element size [3].

Thin substrates with higher dielectric constants are used in microwave circuitry where tight bounding of the fields is desired in order to minimize the undesired radiation and the element size is smaller. In this case there are greater losses, they are less efficient and have relatively smaller bandwidths [4]. Since microstrip antennas are often integrated with other microwave circuits, a compromise has to be made between good antenna and circuit performance.

The microstrip patch can be rectangular, square, dipole, circular and with other shape [1]. The most often used shapes are rectangular and circular, because they are easy to manufacture and analyze, and have good radiation characteristics.

The most common feed configurations for microstrip line are: with microstrip line, with coaxial probe, aperture coupling and proximity coupling. The microstrip line feed is the first type of feed used for microstrip patches and arrays [5]. It is a conducting strip (of much smaller width than that of the patch), placed above the substrate like the patch. The microstrip line is connected to the patch in a position inside his borders. This method is simple to fabricate, easy to match by controlling the inset position, and simple to model. The coaxial-line feed is also very common, it is also easy to do and match, and has low spurious radiation. The noncontacting feed methods use electromagnetic coupling to send energy between the patch and the feed line. The most common noncontacting feed techniques are the aperture coupling and the proximity coupling. In the both there are two substrates which allow independent optimization of the antenna and feed mechanisms, but make the fabrication difficult and the antenna price higher. Taking all this into consideration a survey of microstrip line feed is made.

Impedance matching of rectangular transmission line - fed microstrip patch is investigated in this paper. For evaluation of impedance matching the reflection coefficient (S_{11}) is used. On the ground of the variation of S_{11} the impedance bandwidth of the antenna can be defined. The varying of S_{11} is determined by the input impedance R_{in} of the antenna.

II. EVALUATION OF THE INFLUENCE OF SUBSTRATE ELECTRICAL PARAMETERS

The purpose of the present investigation is to determine the influence of the substrate parameters over the microstrip antenna matching. The effect over the bandwidth has been researched.

Two are the basic substrate parameters that have effect. These are the substrate thickness *h* and its dielectric constant ε_r. They have great influence over the antenna performance, and the choice of dielectric for a substrate is a very important part of the antenna design.

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The structure considered in this analysis is a rectangular microstrip patch, fed by a microstrip line which has a characteristic impedance of Z_c = *100*Ω (Fig. 1). The dimensions of the rectangular patch are calculated for work at frequency of 10GHz. The analysis is done by means of electromagnetic simulator. Initially a case where the resonator is calculated with a standart dielectric – Duroid5880 (with thickness h = *1,588 mm,* and dielectric constant ε_r = *2,2*) is analysed. After that a parametric study is made by changing the values of the thickness h and the dielectric constant ε_r only and keeping all the other values and dimensions constant.

The analysis made so far is incorrect from the point of view of the proper patch calculation for work at 10 GHz, which is also confirmed by the obtained results. It can be seen that the resonant action of the rectangular patch is shifted away from the presupposed frequency as expected. A linear shift of the resonance towards lower frequencies is observed with the increase of both the thickness h and the dielectric constant ε_r .

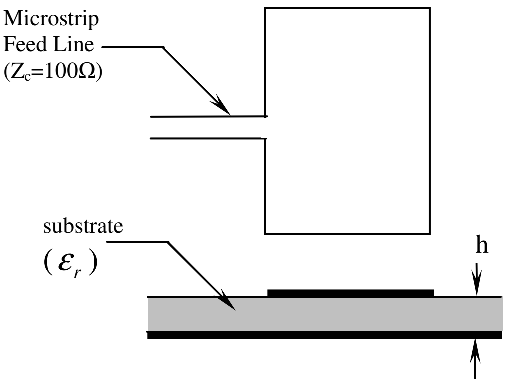

Fig. 1

With the aim of higher accuracy of the parametric study in the second part the case where recalculating the patch dimensions for every single value of the thickness h and the dielectric constant ε_r is analyzed. It can be expected that in this way the antenna resonance will remain about 10 GHz.

III. Results

The input impedance R_{in} and the reflection coefficient S_{11} are shown on Figs. 2 - 5 for the parametric study where only the values of the thickness h and the dielectric constant ε_r are changed. All the other values and sizes are kept unchanged. The same parameters for the second case where the dimensions of the patch are recalculated for every change of the thickness h and the dielectric constant ε_r , are shown on Figs. 6 – 9.

When ε_r is changed in the limits of 2-2,5 (Fig. 6) this has a small effect over the input impedance R_{in}. When ε_r is increased, R_{in} decreases. This can be explained with the fact that at higher values of ε_r there is less radiation, and smaller values of the radiation conductance G_{rad}. The maximum value of R_{in} is getting smaller with higher values of ε_r because of the smaller impedance and the smaller losses.

There is certain shifting of the resonance towards lower frequencies with increase of ε_r as well as similar shifting of the maximum of the input impedance R_{in}. In all of the cases the maximum of R_{in} is not at the resonant frequency for which the resonator has been calculated.

The considerations made so far can be viewed also at S_{11} (Fig. 7). This can be expected because of the direct dependency of S_{11} and R_{in} [1]:

$$\left|S_{11}\right| = \left|\frac{R_{in} - Z_c}{R_{in} + Z_c}\right|. \tag{1}$$

Since the microstrip feed line has a characteristic impedance of Z_c = *100* Ω, the minimum of the reflection coefficient S_{11} can be seen for frequencies for which $Z_c \neq R_{in}$. For these frequencies for which R_{in} has maximum value, it is different from Z_c = *100* Ω, and the matching is worse.

With increase of ε_r lower values of S_{11} can be seen.

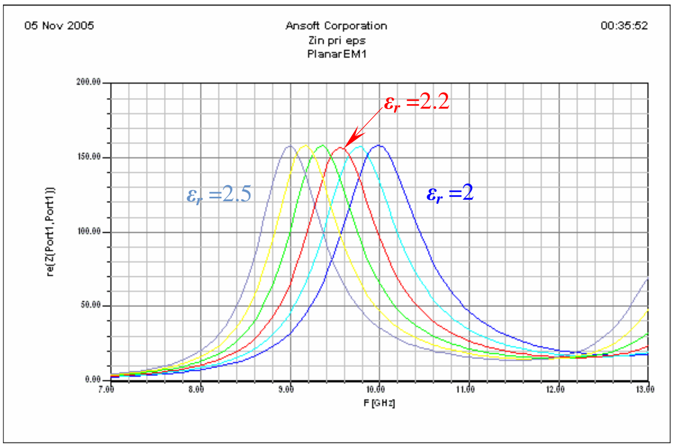

Fig. 2. Rin(f), ε_r = (2, 2.1, 2.2, 2.3, 2.4, 2.5)

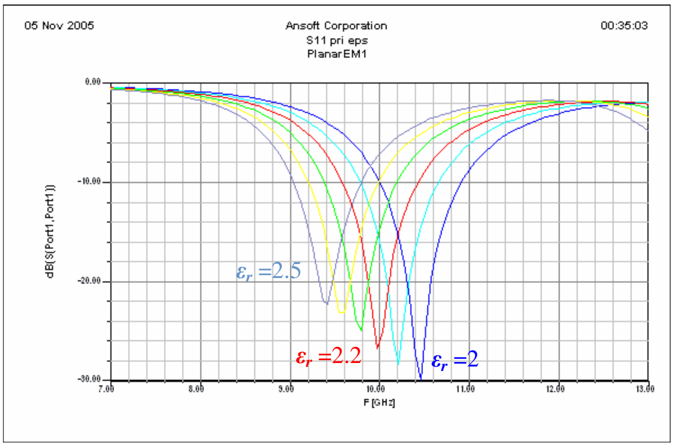

Fig. 3, S_{11}(f), ε_r = (2, 2.1, 2.2, 2.3, 2.4, 2.5)

The influence of the substrate thickness h is much stronger than the influence of ε_r . The higher the thickness h (Fig. 8), the less the radiation, and lower the values of the radiation conductance G_{rad}. The maximum values of R_{in} are all at the same frequency (9,6 GHz), which is lower than the expected for the resonator (10 GHz). The same can be seen also for the reflection coefficient (Fig. 9).

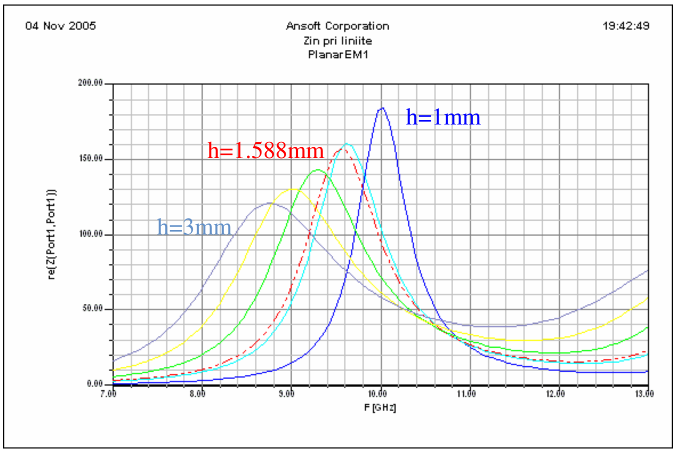

Fig. 4. $R_{in}(f)$, h = (1, 1.5, 1.588, 2, 2.5, 3) mm

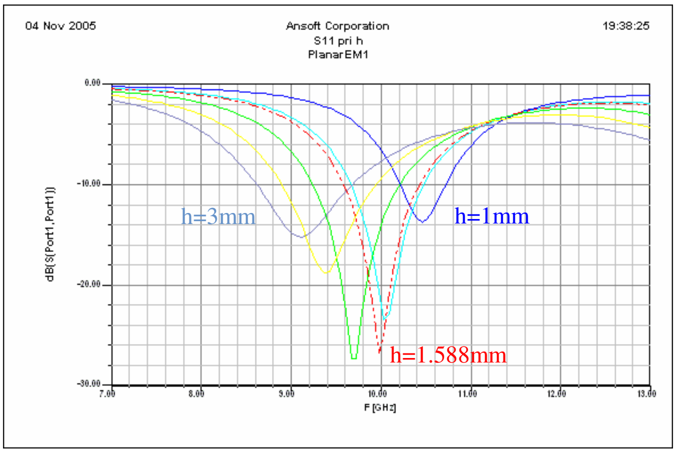

Fig. 5. $S_{11}(f)$, h = (1, 1.5, 1.588, 2, 2.5, 3) mm

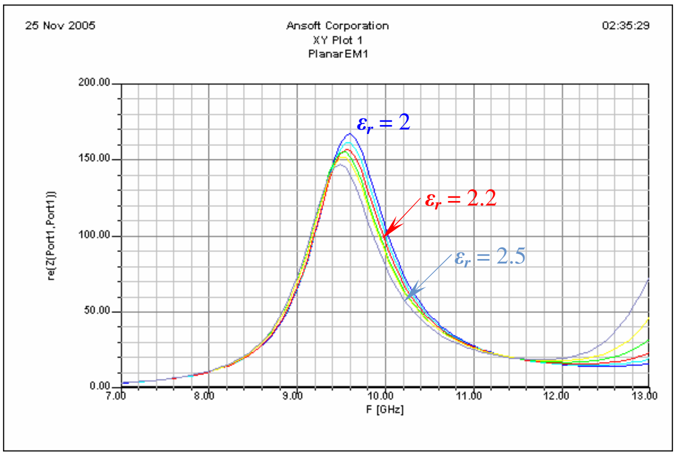

Fig. 6. $R_{in}(f)$, ε_r = (2, 2.1, 2.2, 2.3, 2.4, 2.5)

As for the first analyzed cases (Figs. 2 - 5), and in comparison with the latter cases (Figs. 6 - 9), it can be seen that the shifting of the resonance frequency and the changes in the amplitudes of R_{in} and S_{11} become more pronounced. The reason for this effect is that besides the already mentioned influences there is also the influence of the patch dimensions. This influence is also responsible for the shift of the resonant frequency with increase of the thickness h in Figs. 3 and 4

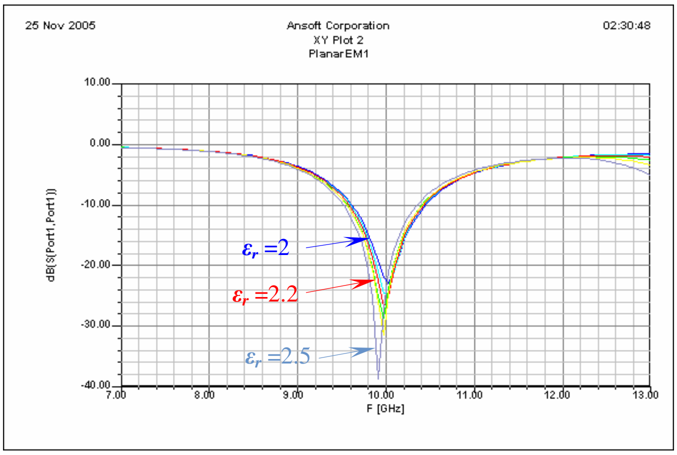

Fig. 7, $S_{11}(f)$, ε_r = (2, 2.1, 2.2, 2.3, 2.4, 2.5)

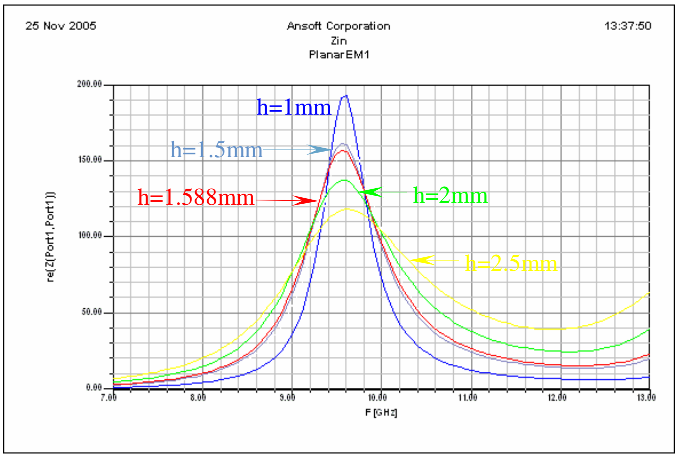

Fig. 8. $R_{in}(f)$, h = (1, 1.5, 1.588, 2, 2.5) mm

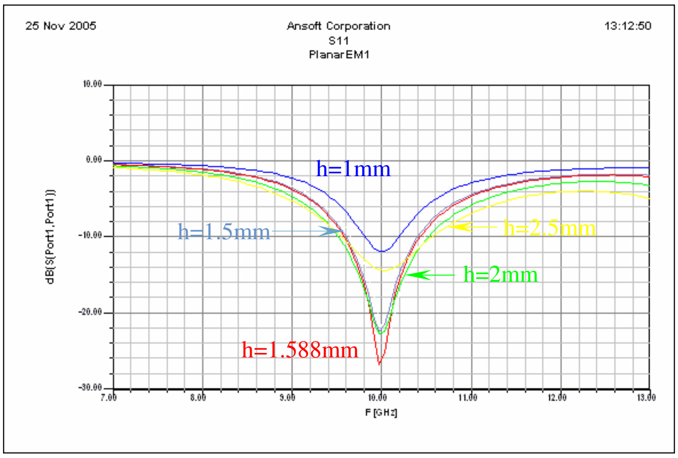

Fig. 9. $S_{11}(f)$, h = (1, 1.5, 1.588, 2, 2.5) mm

IV. CONCLUSIONS

A parametric study of the influence of the substrate parameters (ε_r и h) has been made in this paper. The effect of their variation over the input impedance and over the reflection coefficient of a rectangular patch has been analyzed. Best matching has been reached at higher values of ε_r and middle values of h. With increasing of ε_r there is a change in the resonant frequency, while with varying of h this effect doesn't take place. On purpose of thoroughness of the analysis, the cases of varying of the examined parameter only are analysed, as well as with recalculating the dimensions of the patch for every value of the parameter analysed.

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