Feed Type Influence Over the Bandwidth of Microstrip Patch Antennas

Iva N. Stefanova[1]

***Abstract* –An investigation of the influence of the different type of feed structure for microstrip antennas is made in this paper. A comparison is made of excitation by means of a transmission line, by proximity coupling and by aperture coupling. The analyzed case is that of two parallel-fed rectangular microstrip resonators. The feed structure types that are considered here are compared by means of voltage standing wave ratio.**

***Keywords* – microstrip patch resonators, antenna arrays, feed type structure.**

I. INTRODUCTION

Microstrip patch antennas are dynamic developing section of the antenna field mostly because of their number of advantages – low weight, simple manufacturing, easy installation, aerodynamic profile and naturally low cost. Major disadvantage of the microstrip antennas are their not very good electrical characteristics – low efficiency, low power, poor polarization purity, spurious feed radiation and narrow frequency bandwidth [1]. There are different methods which can be used to increase the efficiency and the bandwidth [2].

The microstrip antenna consist of a very thin metallic strip (patch), placed a small fraction of wavelength above a ground plane. 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 most often 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. 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 have various shape [1]. The most often used shapes are rectangular and circular, because they are easy to manufacture and analyze, and have good radiation characteristics.

In this paper the influence of the different type of the feed structure of microstrip patch resonators is investigated. A comparison is made of excitation by means of a transmission line, by proximity coupling and by aperture coupling (fig. 1). The cases considered are that of a single rectangular patch and also that of two parallel-fed rectangular microstrip resonators. The comparison is made by means of voltage standing wave ratio (VSWR).

II. INVESTIGATION OF THE INFLUENCE OF THE FEED TYPE STRUCTURE

When a choice is made of a type of feed structure of microstrip patch antennas, one of the most important considerations is the bandwidth that any of the possible methods can provide. Next comes the possibilities of ensuring a matching (how many states of freedom are there, or how many are the parameters that can be varied in order to achieve a better impedance match). On a third place is the price of manufacturing the given type of feed structure.

The most common feed configurations for microstrip antennas are: with microstrip line, with coaxial probe, proximity coupling and aperture coupling. The microstrip line feed is the first type of feed used for microstrip patches and arrays [4]. It is a conducting feed strip placed above the substrate like the patch and connected to the patch in a position inside its borders (fig 1–a). This method is simple to fabricate, easy to match by controlling the inset position, and simple to model, but has an inherent asymmetry that generates higher order modes which lead to cross-polarized radiation. In order to overcome some of these problems the noncontacting feed methods can be used. 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 proximity coupling and the aperture coupling. In the both there are two substrates which allow certain independent optimization of the antenna and feed mechanisms, but make the fabrication difficult and the antenna price higher.

The proximity coupling is achieved by placing the patch and the feed structure on different levels. The structure consists of two dielectric substrates as the ground plane is at the bottom of the lower substrate, the patch is on top of the upper substrate and the microstrip feed line is between the two substrates (fig. 1–b). The spurious feed radiation can considerably be reduced by use of thin dielectric with high

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value of dielectric constant, while at the same time the upper substrate can be thicker and with lower dielectric constant so that the radiation of the antenna can be facilitated. To a certain extent the transmission line and the patch can be optimized separately in this way. However a structure with two dielectric substrates is more difficult to analyze because the simple models that were developed for a case of one substrate only cannot be used. The radiation efficiency can be increased by

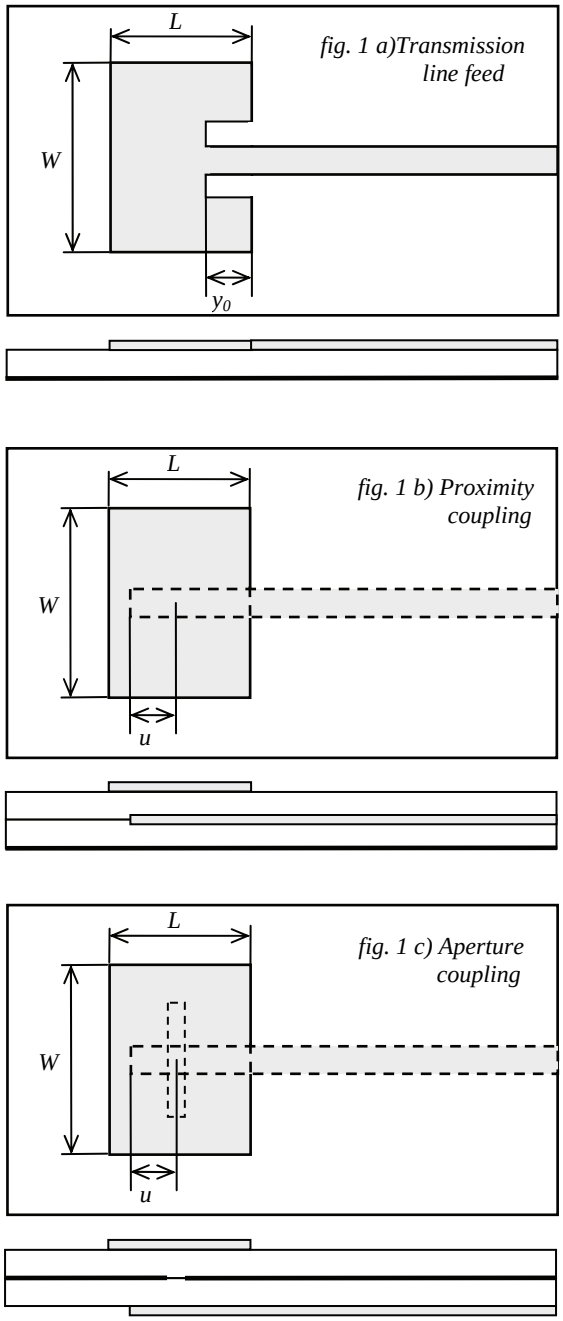

fig. 1 a)Transmission line feed

fig. 1 b) Proximity coupling

fig. 1 c) Aperture coupling

Fig. 1

increasing the distance between the ground plane and the patch. The bandwidth also depends on this distance, and the overlap of the line and the patch has influence over the resonant frequency [5]. The resulting structure becomes more difficult to manufacture because of the presence of two dielectric substrates instead of one, but there is no need of soldering of different conductors as it is in the case of contact feed methods. A disadvantage is the fact that the transmission feed line is not open and there is not direct access to it, so that elements cannot be added to the feed circuit.

The feed by proximity coupling has somewhat large bandwidth and low spurious radiation. The length of the feeding stub and the width-to-line ratio of the patch can be used to control the match. With this type of feed a bandwidth of up to 13% can be achieved [6].

The aperture coupling is most difficult of all to fabricate and it also has relatively narrow bandwidth. However it is easier to model and has moderate spurious radiation. The aperture coupling consists of two dielectric substrates, separated by a ground plane. On the bottom side of the lower substrate is the transmission feed line and the microstrip patch is on top of the upper substrate (fig 1–c). The energy is coupled between the line and the patch through a slot on the ground plane separating the two substrates [7], [8]. In this way the radiating part and the feed part of the antenna are completely separated. For optimization of the mentioned above parts typically a thick substrate with low dielectric constant is used for the top substrate, and material with high dielectric constant for the bottom substrate. The slot ensures coupling of the patch and the feed line but shouldn't radiate, so that energy won't be dissipated towards the backside of the antenna. The slot dimensions must be chosen so that there is no resonance in the working range, and the slot itself must be situated on enough distance from the edge of the patch.

For feeding by aperture coupling the substrate electrical parameters, feed line width and slot size and position can be used to optimize the design [9]. Usually matching is performed by controlling the feed line and the length of the slot [8]. A change in the substrate dielectric constant can lead to an increase in the electromagnetic coupling and does not change the resonant frequency. Increase in the thickness of one of the dielectrics results in decrease of the electromagnetic coupling, which can be compensated by enlargement of the slot.

In the case of aperture coupling the manufacture is harder because two dielectric substrates are involved, connected by a common ground plane. In the metallization a slot must be cut or etched. However there is no need of breaking through dielectrics or soldering of conductors. The feed line is open microstrip transmission line to which additional components easily can be added.

In this paper a rectangular microstrip resonator, calculated for work on 10 GHz and excited by the mentioned above feed types is investigated. A single patch element is examined as well as two parallel-fed patches, so the mutual influence of the resonators and the feed circuit can be established after comparing the results obtained. A case of two elements is investigated since the antenna array theory shows that the mutual influence in a large number of elements can be accounted in pairs and summed afterwards.

III. RESULTS

There are number of methods for taking account of bandwidth. In this investigation a comparison is made in VSWR on a level of 2, which is a common case often used in

practice. The three types of feed are analyzed by means of electromagnetic simulator that uses for calculation the Finite Elements Method. A multitude of simulations with varying of the physical parameters have been conducted till an optimal match in each of the examined cases has been obtained. On figs. 2 – 7 are shown results that illustrate the obtained conclusions.

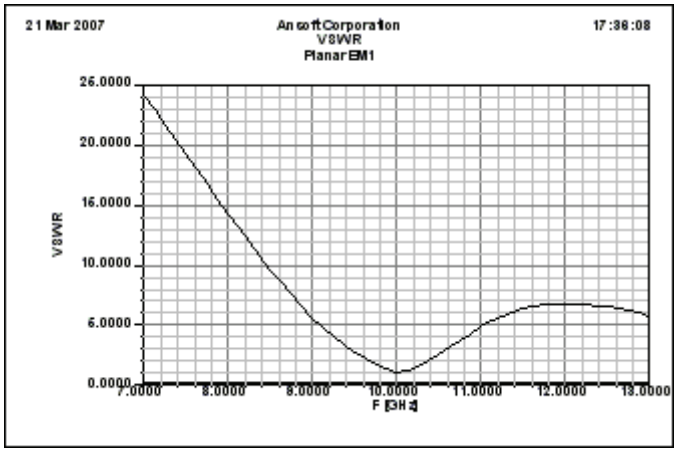

Fig. 2, VSWR, one resonator, transmission line feed.

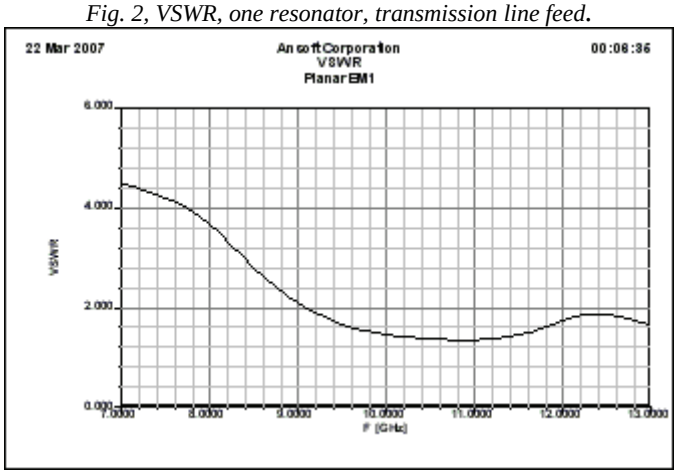

Fig. 3, VSWR, one resonator, proximity coupling.

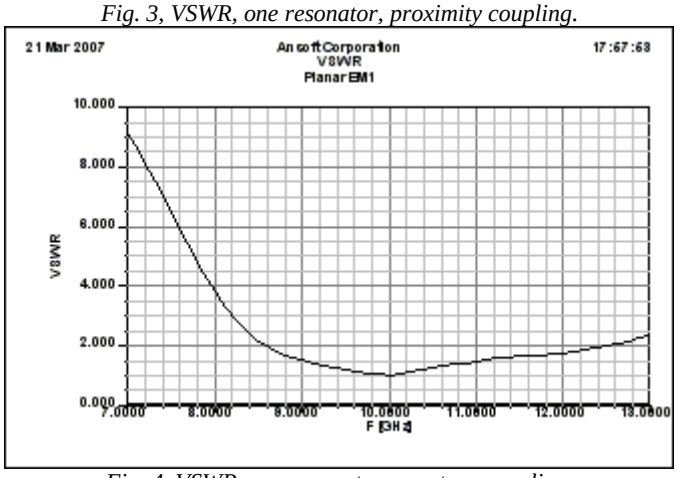

Fig. 4, VSWR, one resonator, aperture coupling.

The voltage standing wave ratio (VSWR) for the three types of feed structure and a single patch are shown on figs 2 – 4. The same types of feed structure, but in the case of two rectangular microstrip parallel-fed patches are shown on figs. 5 – 7.

IV. Discussion

As can be seen from figs. 2 – 4, the results concur with the theoretical investigation. Narrowest bandwidth has the case of transmission line feed, the aperture coupling has considerably larger bandwidth, and largest bandwidth has the case of proximity coupling. The same tendency can be seen in VSWR for two parallel-fed patches (figs. 5 – 7).

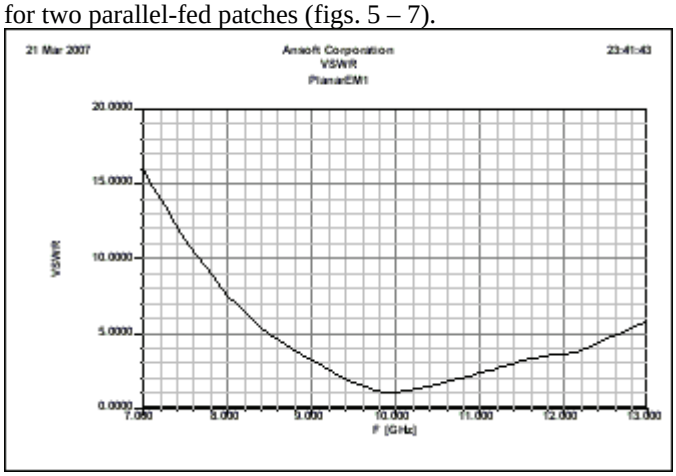

Fig. 5, VSWR, two resonators, transmission line feed.

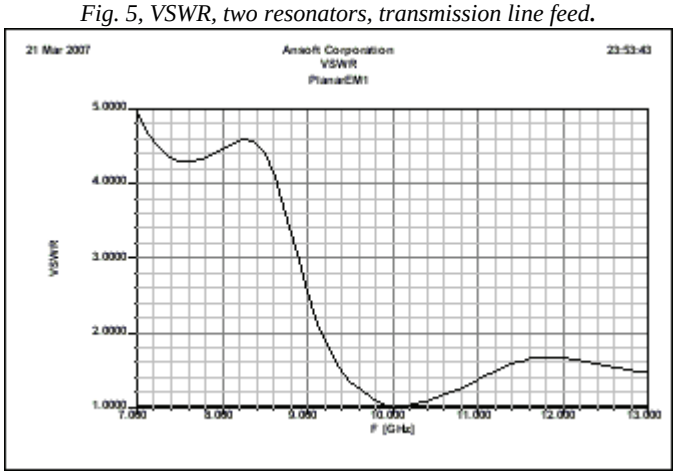

Fig. 6, VSWR, two resonators, proximity coupling.

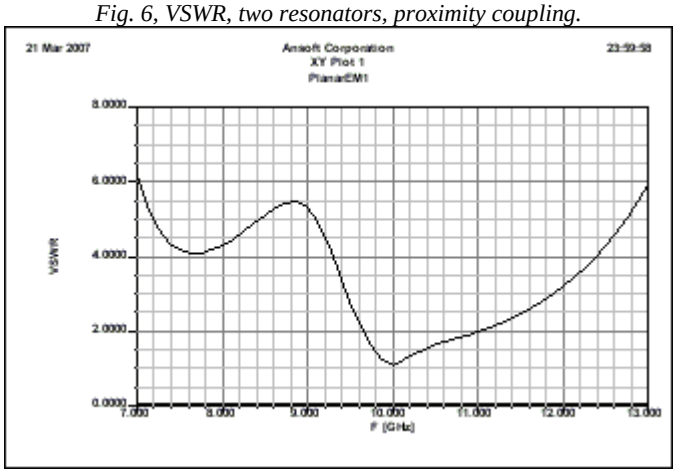

Fig. 7, VSWR ,two resonators, aperture coupling.

When the frequency is changed in the investigated range, the change in VSWR is defined by the change of a number of factors. The first of them is the physical dimensions of the patch (its width and length W and L). The second defining factor is the method used to ensure match – line inset in the

patch y_0 for the case of transmission line feed and line inset u under the patch for the other two cases, as well as the slot dimensions for the case of aperture coupling.

Third defining factor is the mutual influence of the two resonators which can be expressed by means of the mutual resistance R_{12} [1]. It can be accounted that some of the factors mentioned above have contradictory influence – that is, while some of them lead to increase in the resistance, others have the opposite effect. The tendency the bandwidth to become narrower with increase of the number of the elements, that can be expected, is not observed in the case of transmission line feed (figs. 2 and 5).

V. Conclusion

The aim of the present investigation is to evaluate the bandwidth of two parallel-fed rectangular microstrip resonators for three types of the feed structure – transmission line feed, proximity coupling and aperture coupling. The influence of the parallel position of the two patches is taken into account.

From the results obtained in this study it can be seen that the optimal case which combines simplicity of manufacture and maximum bandwidth appears to be the case of proximity coupling. The achieved results can be used during the selection of the feed type structure in microstrip antenna array design.

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