Effect of Microstrip Antenna Feeding in the K-band

Youssef Rhazi [#1], Seddik Bri [#1, 2], Rajaa Touahani [#1]
[#1] System and Telecommunications Engineering Decision Laboratory, Ibn Tofail University
Sciences Faculty of Kenitra, B.P. 133 – Morocco
Corresponding author: rhazi.lastid@yahoo.fr
rtouahni@hotmail.com

[#2] Electrical Engineering Department, High School of Technology: ESTM
Moulay Isamil University, B. P 3103, Meknès – Morocco
briseddik@gmail.com

Abstract— In this paper, we present the simulations results of two types of patch antenna feeding in K-band. The conception of this patch antenna is realized by software HFSS "Ansoft-High Frequency Structure Simulator". The first Feeding uses a uniplanar corner-fed patch antenna presented with single-point microstrip. The second uses the coaxial feed. The aim of our study is to determine the optimal position increasing the return loss.

Keywords: Patch antenna, K-band Design, HFSS, Uniplanar corner fed, Coaxial feed.

I. INTRODUCTION

The enormous development of wireless communication systems requires new wireless devices and systems from scientists to satisfy the requirements of multimedia applications. Multi-frequency and multi-mode devices such as cell phones, wireless LAN networks (WLAN) and wireless personal area networks (WPAN) place more demands on antennas. That’s why the antennas must have a high gain, small physical size, bandwidth, integrated installation [1-4].

However, the patch antenna should promote the industrial world of new technologies that are capable of supporting the speed of development of existing systems. For all these reasons, the bandwidth impedance ratio, polarization axial radiation patterns and gain are becoming the most important factors that affect the application of contemporary and future communication systems by wireless satellite [5].

Feeding methods have great impact in the study and design of patch antennas. These methods can be grouped into two broad categories [6]: the power contact (probe or line microstrip) and power by proximity (online or by electromagnetic coupling slot). The technique used can significantly change the operation of the antenna.

In this paper, we be interested the effect of feeding on the characteristics of a patch antenna (gain, bandwidth, and radiation pattern) especially on loss return, by using two different types of feeding at the point (*dx*, *dy*): With microstrip line that is inserted into the corner of the part in feed [7], and coaxial probe. This can be achieved by varying the same position for *dx* and *dy* values that promote the increase of bandwidth and give the advantage of low radiation losses of the line.

II. THEORY OF PATCH ANTENNA

A microstrip antenna consists of conducting patch on a ground plane separated by dielectric substrate. This concept was undeveloped until the revolution in electronic circuit miniaturization and large-scale integration in 1970 [8]. After that many authors have described the radiation from the ground plane by a dielectric substrate for different configurations.

The patch antenna consists of a metallic conductor wide arbitrary shape called radiating element and deposited on a dielectric substrate. The lower face is completely metalized to provide a ground plane as shown in Fig. 1.

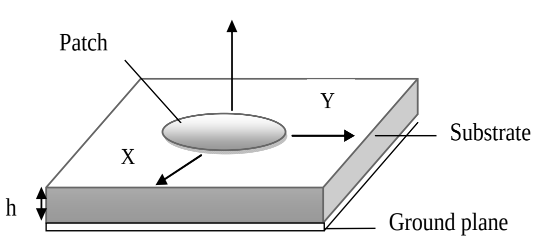


Fig. 1: Microstrip antenna configuration

To simplify the processing and performance prediction, the patch takes usually standard shapes such as square, rectangular, circular, triangular, and elliptical or any other common form.

A. Rectangular patch antenna

The rectangular patch microstrip antenna is the simplest microstrip patch configuration. We can describe the antenna as a strip conductor of dimension (L×W) on a dielectric substrate of dielectric constant ε and thickness h backed by a ground plane.

When the patch is excited, a charge distribution is established on the underside of the patch metallization and ground plane. At a particular moment, the underside of patch is positively charged while the ground plan is negatively charged. This tends to hold a large percentage of the charge between the two surfaces. However, the repulsive force between positive charges on the patch pushes some of these charges toward the edges, resulting in large charge density at the edges. These charges are the source of fringing field and the associated radiation [9].

B. Feeding Methods

The microstrip patch antennas feeding can be classified into two categories: contacting (the microstrip line, coaxial probe) and non-contacting (aperture coupling and proximity coupling).

1) *Microstrip Line Feed:* In this type, a conducting strip is connected directly to the edge of the Microstrip patch as shown in Fig. 2. The patch is wider than the conducting strip. Thus the feed can be etched on the same substrate to provide a planar structure.

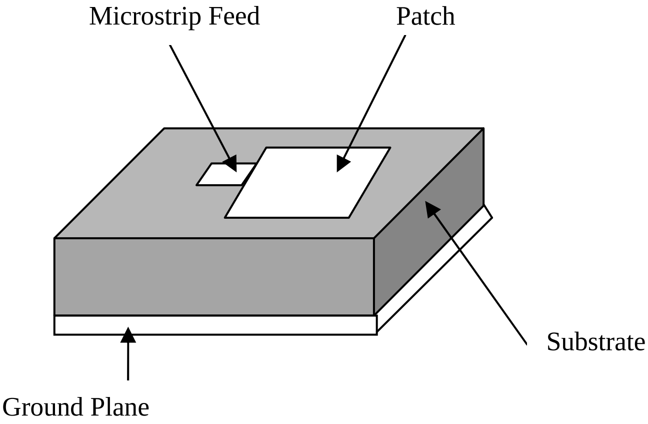


Fig. 2: Microstrip line feed

The purpose of the inset cut in the patch is to match the impedance of the feed line to the patch without the need for any additional matching element. This can be achieved by properly controlling the inset position. Hence this is an easy feeding scheme, since it provides ease of fabrication and simplicity in modelling as well as impedance matching. However as the thickness of the dielectric substrate being used, increases, surface waves and spurious feed radiation also increases, which hampers the bandwidth of the antenna. The feed radiation also leads to undesired cross polarized radiation.

2) *Coaxial Feed:* The coaxial feed also called probe feed is the most used technique used for feeding microstrip patch antennas. The inner conductor of the coaxial connector extends through the dielectric and is soldered to the radiating patch, while the outer conductor is connected to the ground plane. What is important of coaxial feeding is that it can be placed at any desired location inside the patch in order to match with its input impedance. The advantage of this feed method is that it can easily be fabricated and can have low spurious radiation. However, a major disadvantage is that it provides narrow bandwidth and is difficult to model. Thus not making it completely planar for thick substrates ($h > 0.02\ \lambda_o$). Also, for thicker substrates, the increased probe length makes the input impedance more inductive, leading to matching problems.

3) *Aperture Coupled Feed:* In this type, the patch and the microstrip feed line are separated by the ground plane as indicated in Fig. 3. Coupling between the patch and the feed line is made through a slot in the ground plane.

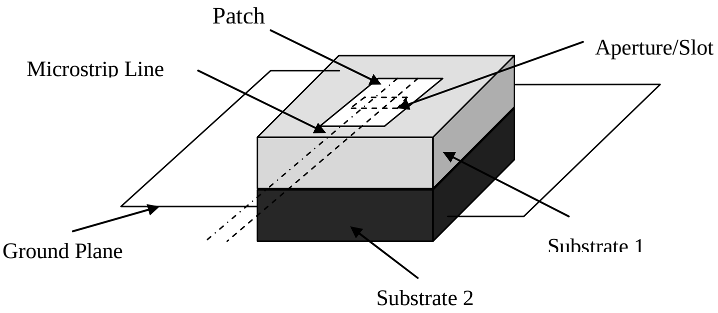


Fig. 3: Aperture-coupled feed

The coupling aperture is usually centered under the patch, leading to lower cross polarization due to symmetry of the configuration. The amount of coupling from the feed line to the patch is determined by the shape, size and location of the aperture. Since the ground plane separates the patch and the feed line, spurious radiation is minimized. Generally, a high dielectric material is used for bottom substrate and a thick, low dielectric constant material is used for the top substrate to optimize radiation from the patch. The major disadvantage of this feed technique is that it is difficult to fabricate due to multiple layers, which also increases the antenna thickness.

4) *Proximity Coupled Feed:* In this type of feed two dielectric substrates are used such that the feed line is between the two substrates (Fig. 4). The radiating patch is on top of the upper substrate. The main advantage of this feed technique is to provide very high bandwidth. This scheme also provides choices between two different dielectric media, one for the patch and one for the feed line to optimize the individual performances.

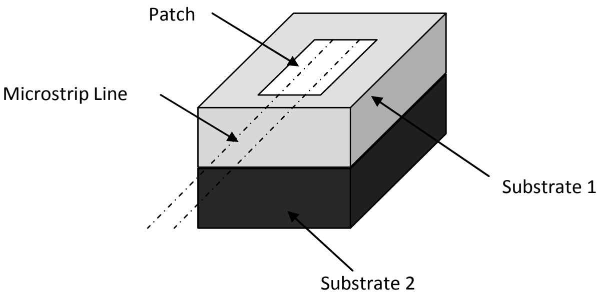


Fig.4: Proximity-coupled Feed

Matching can be achieved by controlling the length of the feed line and the width to- line ratio of the patch. The major disadvantage of this feed scheme is that it is difficult to fabricate because of the two dielectric layers which need proper alignment. Also, there is an increase in the overall thickness of the antenna.

5) Characteristics of microstrip patch antennas: Whatever the shape or size of the patch antenna, they are characterized with the same specifications [10]. The antennas are generally adapted to an impedance of 50 ohms [9]. The input impedance varies proportionally with the frequency even if the intrinsic impedance of the feeding remains unchanged. Generally input impedance is the ratio between the voltage and currents at the antenna port. The gain of an antenna (in any given direction) is defined as the ratio of the power gain in a given direction to the power gain of a reference antenna in the same direction. For any patch antenna the gain according to the directivity (D) and the return loss (ρ): $G(\theta,\varphi) = \rho * D(\theta,\varphi)$

It is important to note that an antenna with the gain does not create the radiated power. The antenna leads just as the radiated power is distributed with respect to the power of radiation in all directions and the gain is just a characterization of how the power is radiated [11]. The radiation or antenna pattern describes the relative strength of the radiated field in various directions from the antenna, at a constant distance. The radiation pattern is a reception pattern as well, since it also describes the receiving properties of the antenna. The radiation pattern is three-dimensional, but usually the measured radiation patterns are a two-dimensional slice of the three-dimensional pattern, in the horizontal or vertical planes [12].

C. METHOD OF ANALYSIS

There are several methods for the analysis of patch antennas, but the transmission line model is the simplest and most commonly used in the literature [13] since it gives a good understanding of physics, however, there are other models such as cavity model and full wave model.

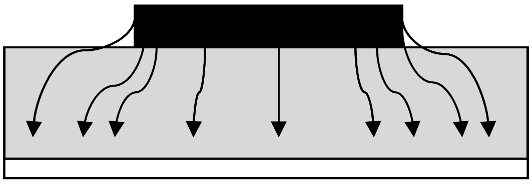


Fig.5: Fringing field between patch and ground plane

Considering Fig.5 which represents the model of transmission line we notice that most of the electric field lines move through the substrate except for a few lines out into the air. Therefore, the transmission line can not support pure transverse electric magnetic (TEM) mode of transmission, since the phase velocities would be different in the air and the substrate. Instead, the dominant mode of propagation is quasi-TEM mode. Therefore, an effective dielectric constant should be obtained to take account of the fringe and the wave propagation in the line [14].

$$\varepsilon_{ref} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left(1+\frac{12h}{w}\right)^{-0.5}$$

Where:

ε_r is the effective dielectric constant

ε_{ref} is the dielectric constant of substrate

h is the height of dielectric substrate

W is the width of the patch

The normal components of the electric field at the two edges along the width are in opposite directions and thus out of phase since the patch is *λ/2* long and hence they cancel each other in the broadside direction. The fringing fields along the width can be modelled as radiating slots and electrically the patch of the microstrip antenna looks greater than its physical dimensions. The dimensions of the patch along its length have now been extended on each end by a distance ΔL:

$$\Delta L = 0.412h\frac{\varepsilon_{ef+0.30}}{\varepsilon_{ef-0.258}}\left(\frac{{}^{W}\!/_{h}+0.264}{{}^{W}\!/_{h}+0.813}\right)$$

The effective length of the patch L_{eff} :

$$L_{eff} = L + \Delta L$$

III. SIMULATIONS RESULTS

A rectangular microstrip antenna with a single radiating element and dimension well defined, feeding with two different ways by changing the coordinates of feeding (Fig.6 and Fig.7).

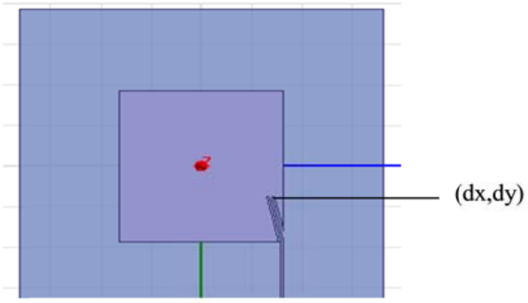


Fig.6: Configuration of feeding by microstrip line feed

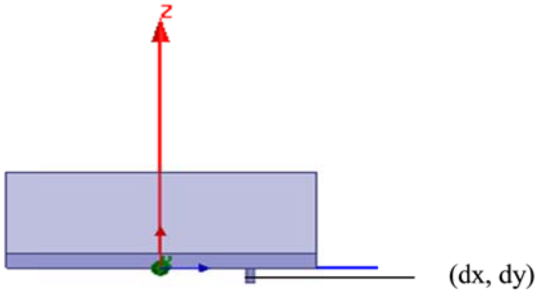


Fig.7: Configuration of feeding method 2 (coaxial fed)

We have opted for the realization of our antenna configuration shown below in Fig.8. The substrate used is DiClad 880 ($\varepsilon_r = 2.2$) with a thickness of 0.508mm and the patch dimensions equal to (7.46×6.54) mm^2 [7].

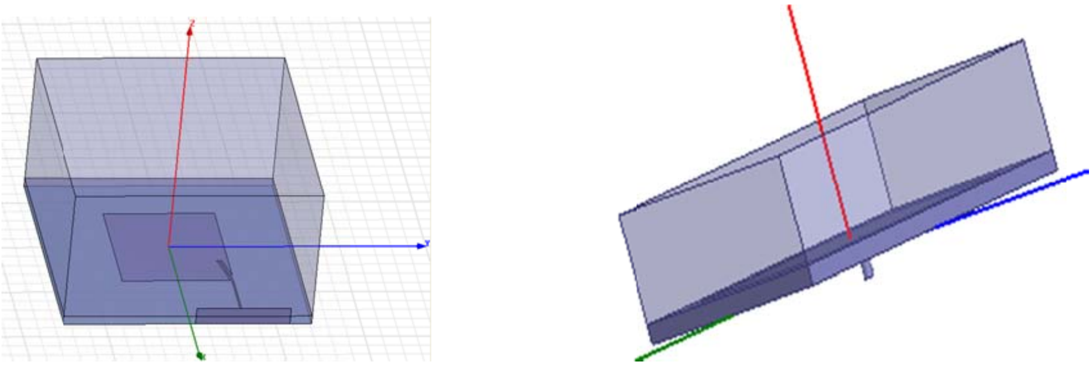


Fig.8: Design of the rectangular patch antenna by HFSS (a) Fed by microstrip line (b) Fed by coaxial probe

The position of the feed line microstrip designated by *dx* takes the following values: 1, 1.5 and 2 mm; while *dy* is fixed at 2.6 mm (Fig.6). Results are obtained by Ansoft HFSS simulation below (Fig. 9).

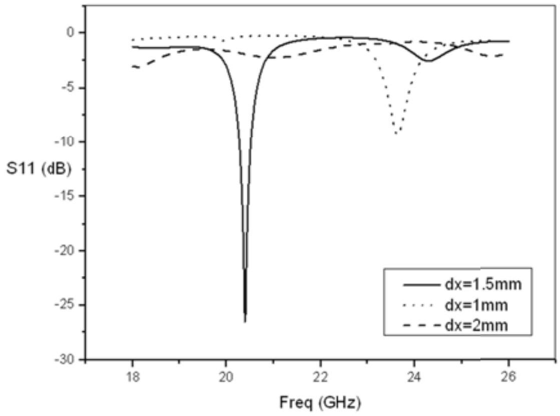


Fig.9: Variation in Return loss S11 depending on the frequency K-band with dy = 2.6 mm (microstrip line feed)

After analyses the S11-parameter simulation result from Table I for the microstrip line feed. The result has shown that the value maximal return loss |S11| is 25 dB; for dx=1.5 mm; with a resonance frequency 20.3 GHz.

TABLE I

Results of simulation of the antenna

Value of dx (mm)	**Resonance frequency (GHz)**	**Return loss |S11| (dB)**
1	24	10
1.5	20.3	25
2	21	< 10

Through the same way, the position of the coaxial feed takes the following values: 1, 1.5 and 2 mm; while *dy* is fixed at 2.6 mm (Fig.7). Results are obtained by Ansoft HFSS simulation below (Fig. 10).

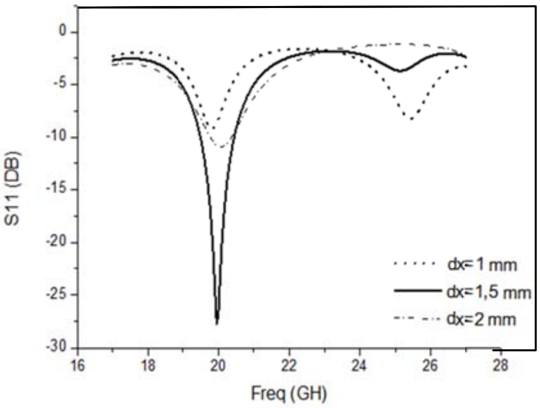


Fig.10: Variation in Return loss S11 depending on the frequency K-band with dy = 2.6 mm (coaxial feed)

After analyses the S11-parameter simulation result from Table II for the microstrip line feed. The result has shown that the maximal value return loss |S11| is 30 dB; for dx=1.5 mm; with a resonance frequency 20 GHz.

TABLE III

Results of simulation of the antenna

Value of dx (mm)	**Resonance frequency (GHz)**	**Return loss |S11| (dB)**
1	19.88	< 0
1.5	20	30
2	2.3	10

We deduce that in K-band that the best position of the feeding line and the feeding coax is the position dx = 1.5mm which gives return loss of 25 dB compared to other positions (Fig.9 and Fig.10). The position of the feed line microstrip designated by *dy* takes the following values 1.5, 2 and 2.5 mm while *dy* is fixed at 1.5 mm (Fig.11). Results are obtained by Ansoft HFSS simulation below.

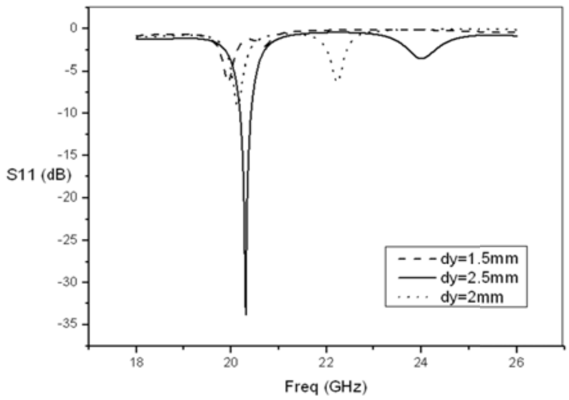


Fig.11: Variation in Return loss S11 depending on the frequency K-band with dx = 1.52 mm (microstrip line feed)

Through the same way, the position of the coaxial feed designated by *dy* takes the following values 1.5, 2 and 2.5 mm while *dx* is fixed at 1.5 mm (Fig.12). Results are obtained by Ansoft HFSS simulation below.

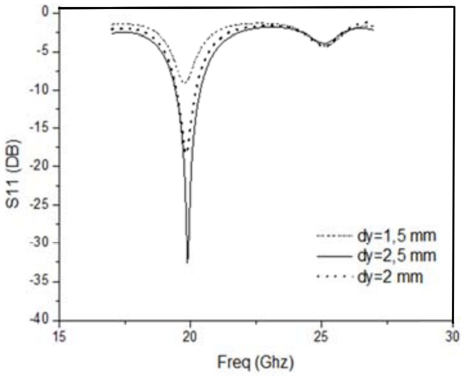


Fig.12: Variation in Return loss S11 depending on the frequency K-band with dx = 1.52 mm (coaxial feed)

The most of the energy was absorbed by the antenna for both types of feeding in the position dy = 2.5 mm. The return loss is approximately equal to 35dB (Fig.11, Fig.12).

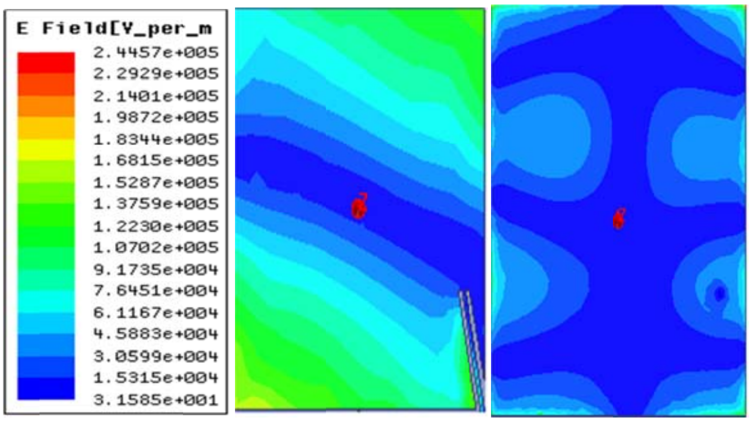
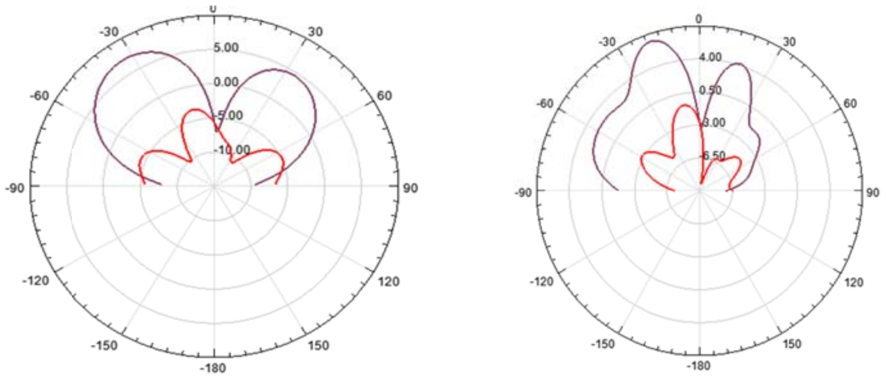


Fig.13: E-Field pattern

(a) fed by coaxial probe (b) fed by microstrip line



(b)

Fig.14: Radiation Pattern (a) fed by coaxial probe (b) fed by microstrip line

Radiation patter results have been presented in m Fig.14. The patterns are directive and notice that the antenna configuration is the same, feeding by two different methods. The coaxial probe gives the best results.

IV. CONCLUSION

The choice of the position of the feeding depends on their performance of the patch. The conception of antennas using HFSS bases essentially on the shape of the patch antenna and the feeding method and the substrate in order to obtain a result which return loss wished. In this study the return loss is maximum in the position dx=1.5 mm and dy=2.6 mm. The advantage of the fed by a coaxial cable compared to the feed Microstrip line is that the impedance corresponding to the K- band can be adjusted. For all this the coaxial feeding stays the preferred feeding compared to microstrip line feeding. The feature works of this research will be interested to network array of path antenna.

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