DESIGN OF A COMPACT SIZE EXCITATION DEVICE FOR ANTENNA PATTERN USING FRACTAL ARCHITECTURES

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ABSTRACT

This paper presents the design and the implementation of a device which can properly feeds an antenna composed of three simple radiating elements operating at 2.45GHz. The designed antenna is of planar type, compact and quite isotropic. Compact size means that the excitation device has to be as small as possible in order to be integrated on the same substrate as the radiating elements. On the hand the excitation device must not affects significantly the radiation pattern. There are several ways to obtain a phase shift of 90° or 180°: by using couplers or by splitting the signal into two parts and adjusting the length of the microstrip lines. It is clear however that both these solutions would require a lot of space and an oversized ground plane. For this reason, we decided to design a device using fractal architectures. Its main advantage is that it does not affect the radiation pattern too much and respects the size specifications. A complete antenna has been realized on epoxy substrate. Experimental results confirm the theoretical prediction. In addition, this principle could be used to create even smaller devices by using higher permittivity substrates such as alumina.
RF Wireless systems are gaining in interest for many applications like communication, identification and localization. The need for low cost and isotropic antennas is one of the most attended issues from system designers. The objective of this communication is to address the design of quite versatile antenna in terms of isotropy and size [1]. The basic idea behind this work is the association of simple antenna elements and their integration into the same substrate. One of the problems to be solved is the excitation system which must be taken into account during the design procedure and have to be size compatible with the final antenna device. Indeed, the feeding system, which is mainly a network of transmission lines with appropriate characteristics in terms of impedances and length must excites the elementary antennas according specific signal levels and phases [2]. The size of the feeding network has to be as small as possible in order to be integrated with the antennas. A special attention need to be given to this constraint.

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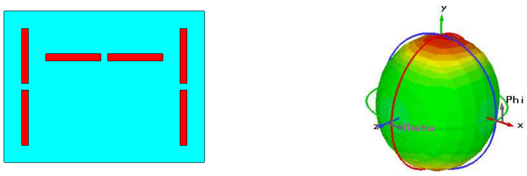
INTRODUCTION

The studied antenna is thus composed of three λ/2 dipoles printed on a substrate (epoxy in our case) as shown in Fig. 1a. The spatial position of the dipoles and the excitation signals will influence strongly the radiation pattern as shown in Fig. 1b. So, dipole positions and excitation signals are the two key elements in the design procedure.



a) b)

Fig. 1. a) The position of the three λ/2 printed dipoles; b) Simulated 3D pattern diagram of the antenna corresponding to an in-phase excitation.

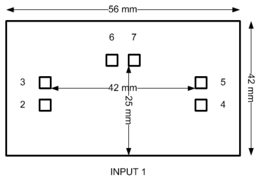


Fig. 2. Card dimensions and excitation port map.

The antennas are integrated onto a card as shown in Fig.2. As we previously calculated the phase shift values between the dipoles, it is clear that the two lateral dipoles must be 90° phase delayed with respect to the center one. So, to simplify, Arg(S16) is supposed to be nil. Thus, we can easily define all the phase shifts as follow in Table 1.

TABLE I : Summary of Phase Shifts

	S12	S13	S14	S15	S16	S17
Arg(S)	90°	270°	90°	270°	0°	180°

To sum up, there are still several problems to solve: the available free space on the card is limited, the antenna radiation pattern must not be affected by the excitation device and the phase shift must be generated as precisely as possible.
In the next part of this paper we are going to look at the traditional ways of splitting a signal and also at how phase shifts are obtained. After, some more suitable solutions will be investigated. The suggested design will be presented with the most important design parameters. At the end of the paper, the suggested design will be demonstrated with some theoretical and practical results.

POSSIBLE COMPONENTS AND SOLUTIONS

Two solutions will be discussed: the use of the couplers and a method for line length adjustment.

Couplers

There are simple couplers which allow 90° and 180° phase shifts to be generated. A 3dB hybrid coupler is a four-port device that is used to equally split an input signal with a resultant 90° phase shift between output signals. As for the ring coupler, it is also a four-port device that is used to equally split an input signal, but the resultant phase shift between output signals is 180°.
Even if the hybrid and ring couplers are easy to design, neither the hybrid nor the ring fit the specifications mainly because of their size; the ring coupler has a 15.8 mm radius and the hybrid coupler a length of 17 mm. The ground plane required for the couplers is also a problem because it is as big as the couplers themselves. Furthermore, the couplers are composed of λ/4 lines which would also generate resonance and anti-resonance at working frequency.

Line Length Adjustment

Method for microstrip line length adjustment: the principle is simple; the input signal is divided into as many parts as necessary. Then the length of the line between the input and port excitation has to be well calculated. Once the length of each line has been defined, the shape of each line must then be designed so that it reaches its port properly.
To use this method a ground plane is necessary and some parts of line are λ/2 or λ/4 long. Therefore this solution would also generate resonance and anti-resonance.

IMPLEMENTATION WAYS

Two solutions seem to be suitable to reduce the size of the excitation device we have to design without using more place than presented in Fig. 2. Fractal and multilayer architecture.

Fractal Architectures

Fractal architectures allow us to reduce size of couplers according to [3] by using Von Koch curves as demonstrated in [4].
As described in [3], it's possible to design a ring coupler using Fractal architectures. This allows reducing total size of coupler by 57%. In order to reach this result, the line impedance has been increased to reduce the line width. By using this coupler, the $\lambda/2$ or $\lambda/4$ long lines are divided in smaller ones. So resonance and anti-resonance are still present but not at the operating frequency. Nevertheless, this coupler still occupies too much place because some of these couplers would be needed to realize the complete excitation device.

Multilayer Architectures

Multilayer architecture allows us using the third direction by increasing thickness without having any influences over width and length of card. However, whatever is the solution selected, the ground plane size and position need to be optimized.
The design of the ground plane has been done by evaluating in a visual way effects on 3D radiation pattern. So we simulate the dipole association in presence of ground plane for various sizes of this one. Thus we decide if the damages on the radiation pattern are acceptable or not.
It is clear from Fig. 3 that the ground plane affects the radiation pattern of the antenna because a strong loss of isotropy is observed. We optimized the ground plane size in order to maintain a high isotropy characteristic. To be suitable, its size has to be 25 mm x 34 mm.

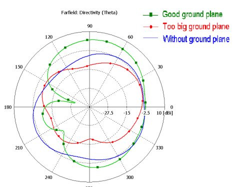


Fig. 3. Radiation pattern for several ground planes.

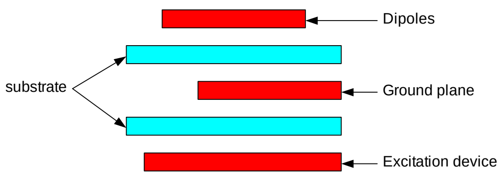
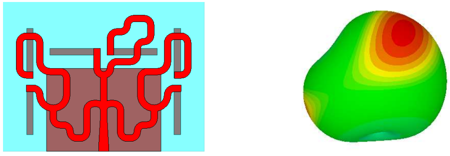


Fig. 4. The multilayer structure used for our device.

Multilayer allows us to gain additional surface for the excitation device. Each added layer generates a net surface equal to the card surface as shown in Fig. 4. The distance between the dipoles and the excitation device is increased by the thickness of the substrate.
Consequently, coupling effects are reduced. The dipoles and the excitation device are linked by cylindrical via-hole.

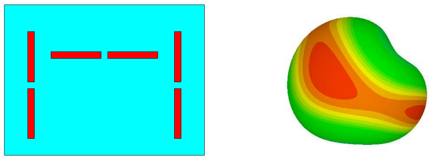
THE SELECTED SOLUTION

The solution is a combination of multilayer and fractal architectures. Thus the available space is at its maximum, there are no damages on the radiation pattern and coupling effects are reduced. In order to realize the device, the impedance of the line has been increased to reduce its width. Parts of line in arc of a circle were used to create the phase shift. Arcs of a circle allow us to avoid creating parasite resonance due to the $\lambda/2$ or $\lambda/4$ long lines. Fringing effect will be avoided too.
It is now possible to simulate the dipoles associated to the excitation device. Several far field 3D radiation patterns corresponding to different views have been obtained by using CST Microwave Studio. Figs. 5 show top view (towards dipoles) of the antenna and the corresponding radiation pattern. Figs. 6 are relative to the bottom (towards the excitation device) view.



a) b)

Fig. 5. a) Top view of the antenna; b) Top view of the far-field radiation pattern.



a) b)

Fig. 6. a) Bottom view of the antenna; b) Bottom view of far-field radiation pattern.

Results show that radiation pattern of the antenna has been affected by the excitation device. However, the result is rather convenient because there is no too strong attenuation. It remains now to verify by realizing a model that such results can be reached

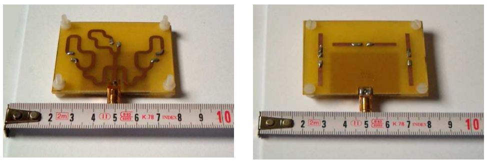


Fig. 7 Bottom view of the realized antenna : Fractal exciting architecture side and Top view of the realized antenna: dipoles side

Using the simulation results, we realized a complete device on epoxy substrate. Fig. 7 shows top and down views of the realized device. One can clearly identify the three radiating dipoles and the excitation system with its fractal geometry. As experimental characterization we measured the S11 of the complete system with a vector network analyzer in the 2 to 3 GHz range and the diagram pattern at 2.45 GHz in an anechoic room.

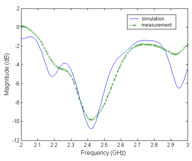


Fig. 9. Comparison between measured and Simulated results for S11 reflection coefficient.

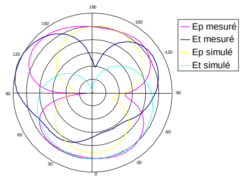


Fig. 10. Comparison between measured and Simulated diagram patterns at 2.45GHz.

Figs. 9 and 10 show the experimental results as well the theoretical one obtained by simulation using CST Microwave. The global shape of the curve of S11and diagram patterns are not modified Fig. 9 shows that the result is particularly interesting. Whereas the results of simulations indicated a bandwidth of 140 MHz around the frequency of resonance 2.43 GHz, measurement indicates a bandwidth of 200 MHz around 2.427 GHz.

Differences between simulation and measure on Fig. 10 are mainly due to the uncertainty on the permittivity of the substrate and perhaps to the aging of the prototype.

CONCLUSION

This paper focuses on the excitation of multiple radiating elements such as printed dipoles. We demonstrated that it is possible to realize a compact excitation device over epoxy substrate without using more space than the antenna offers itself. These results allow isotropic, compact and low-cost antennas to be created. More compact size device are possible with high permittivity substrates. This kind of antenna would be used in most applications operating at the 2.4 GHz band such as RFId, Bluetooth or Wifi.

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