GRUPO DE RADIOFRECUENCIA

Universidad Carlos III de Madrid

Departamento de Teoría de la Señal y Comunicaciones

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I INTRODUCTION

The Radiofrequency Group at the Universidad Carlos III in Madrid was officially created in 2005, although the group in the University was recognized since 1997. Nowadays, it is composed of 7 professors and 6 Ph students. The members of the Group are in charge of all the courses in Electromagnetic Fields, Microwave Engineering and Antennas at the Universidad Carlos III in the Ingeniería Técnica and Ingeniería Superior degrees of Telecommunication.

The facilities of the group can be summarized as follows:

Students Laboratory:
Waveguide Benches.
3 and 4 GHz Vector Network Analyzers
3 and 6.5 Spectral Analyzers
Noise Measurement

Research Laboratory:
6 GHz and 50 GHz Vector Network Analyzers.
6.5 GHz and 30 GHz Spectral Analyzer.
Noise Measurement.
Power Measuring.
Anechoic Chamber (Due during 2006).
Printed circuits laboratory .(hybrid technology).

The research lines of the group can be summarised as:

1) Microstrip antennas for broadband and multifrequency applications. 2) Active antennas: broad band, high efficiency and mixing active antennas. 3) Numerical methods for antenna analysis and design. 4) New periodic materials for antenna applications: Frequency Selective Surfaces (FSS) and Metamaterials. 5) Smart Antennas and 6) Ultra Wide Band antennas for radio diffusion applications.

During these years the Group has led four Official Public Research Projects and has taken part in ten private projects.

II Microstrip Antenna for Broadband and Multifrequency Applications

Among the various shapes of microstrip antennas, the rectangular and circular patches are the ones that have been more extensively studied. These patch antennas have a ring version that constitutes an alternative to the standard shape. Several interesting properties are associated with ring patch antennas. For the classical version (open ring), the size of the resonant ring can be smaller than the one of the corresponding circular patch. This makes these antennas useful for cases where low directivity is necessary. However, the open circuit condition in both the inner and outer radii causes sometimes difficulties in antenna feeding.

An alternative to the classical open ring patch is the short circuited ring patch done by incorporating a shorting rod at the center of a circular patch. This change in the field distribution allows easy feeding (not higher input impedance anymore) and also has new possibilities and advantages such as the reduction of surface waves propagation along the substrate if the ring is designed with particular critical dimensions as it has been proposed. Particular attention has been paid to the fundamental mode: the TM_{01}. This mode exists in all patch geometries but as a higher order mode, whilst in the short circuited ring patch is the mode with the lowest resonant frequency, i.e. the "dominant", as it will be showed in this work. The radiation pattern of the TM_{11} mode and the one of the TM_{01} mode are completely different. The first one is a "dipolar" mode (similar to the TM_{10} for rectangular geometries) whilst the TM_{01} mode provides a "monopolar" radiation pattern.

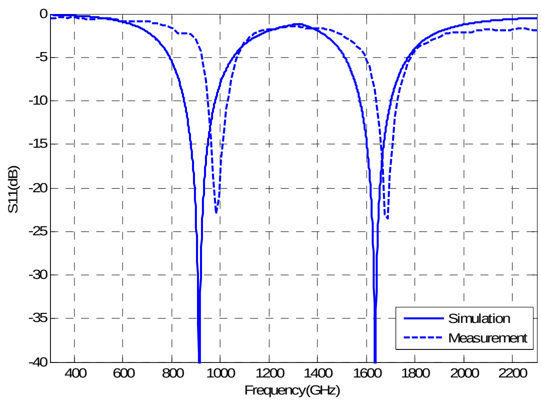

Figure 1: Impedance behaviour of the short circuited ring patch

The application will define which one of the modes is needed. Nevertheless, only with the short circuited ring patch geometry it is possible to have a monopolar radiation pattern in a patch antenna keeping the antenna size small. In this way, the short circuited ring patch differs from the open circuited one where the fundamental mode is the TM_{11}, as in the circular patch. It can also be emphasized that these modes behaviour (monopolar radiation pattern for the fundamental TM_{01} mode and dipolar radiation pattern for the classical TM_{11}) allows this antenna to be used as a dual frequency dual mode antenna for an application such as a dual GSM-GPS antenna. The radiation patterns for any mode can be seen in figure 2:

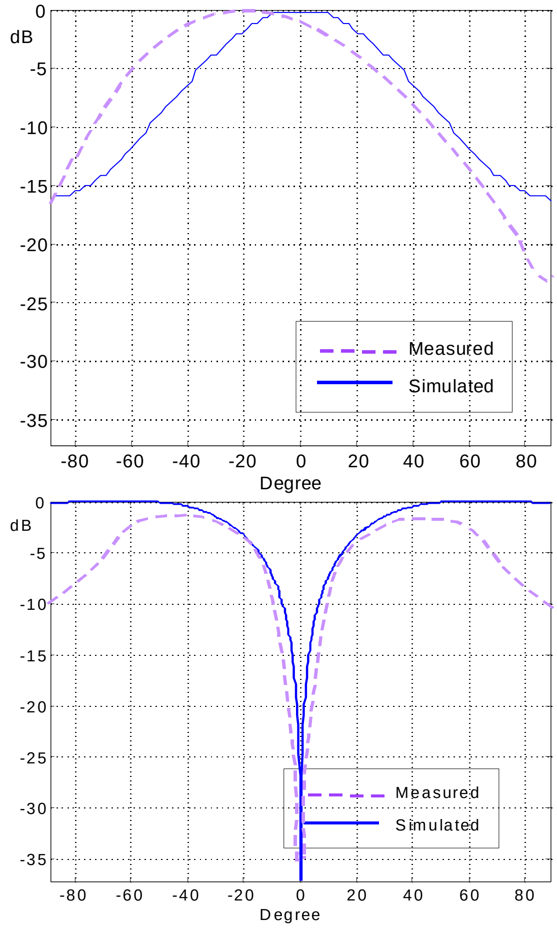

Figure 2: Radiation patterns for TM01 (down) and TM11 (up) modes

III Active antennas

Active antennas have the advantage of integrating in the antenna itself some of the functions of the transmitter or the receiver. Efforts have been done in integrating the amplifier in the antenna resulting in an increase of both, the effective gain of the antenna and the figure of merit (G/T). The aims in this point are to achieve: broadband, high efficiency and mixing.

A. Broadband active antennas

The design of broadband active antennas has not received very much attention until now. This task requires that both, pattern and circuit parameters, show a broad bandwidth behaviour. Then, the design of broadband active antennas will have to deal simultaneously with broadband amplifiers and broadband antennas design techniques.

Concerning the broadband amplifying characteristics several topologies can be used: reactive equalisation, resistive equalisation, feedback and distributed amplifiers. Although the reactive equalisation technique has been used by some authors, it did not provide a compact design either a direct connection between the antenna and the amplifier; besides, the reactive matching network can present stability problems for very broadband structures. Using a feedback or a distributed topology would imply a noisy or non compact design. The resistive equalisation technique provides a compact design but it lacks, a priori, a noiseless characteristic. A new approach for the design of an amplifying active receiving broadband antenna by using a modified resistive equalisation technique has been proposed. The resistive equalisation technique will broaden the impedance bandwidth from the antenna and the circuit point of view. The choice of the amplifier source impedance near the minimum noise impedance of the MESFET and the inclusion of high impedance lines with the equalising resistors will allow a noiseless design of the broadband active receiving amplifying antenna. In this way, the resistive loading technique proposed in this paper makes the active antenna increase its bandwidth characteristics and its effective gain characteristics because of the presence of the active element. Besides, it also maintains a low noise level thanks to the presence of the high impedance lines so the G/T and its corresponding bandwidth will also be increased vs. its passive counterpart.

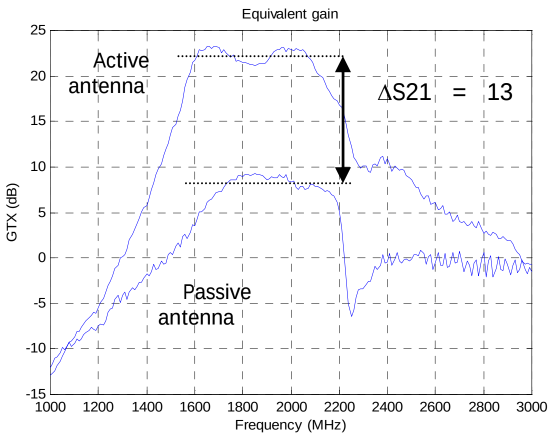

Figure 3: Increased of the equivalent gain in the broadband active antenna vs the passive antenna.

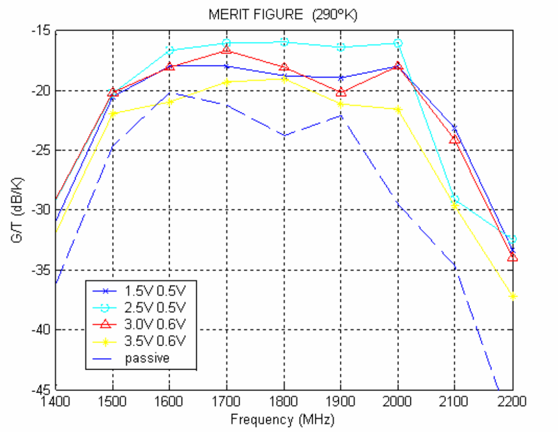

Figure 4: G/T in the active (several bias) and passive antenna

The technique of resistive loading for construction of active antennas has been shown as a suitable one to increase both the impedance bandwidth of the antenna, active antenna gain and G/T parameter. An antenna working in the DCS-UMTS has been presented with an active antenna gain 12 dB larger than the corresponding of the passive antenna. An increase in the operating bandwidth has also been obtained. Relative planar G/T at a level of -16 dB/K with a ripple of 0.5 dB has also been obtained; this implies an improvement of around 6 dB in the whole antenna bandwidth.

B. High efficiency active antenna

In the most of cases the concept of high efficiency has been studied in transistors, but unfortunately there are very few applications to antenna. We are showing that a patch antenna adequately fed can work as a high efficiency active patch (HEAP) antenna. The main problem is to determine the dimensions, shape and the location of the feeding point in the active patch antenna.

The high efficiency is achieved by the synthesis of the optimum output load at each harmonic and using the adequate matching network. The main task is to determine whether the antenna presents a feeding point showing the optimum load at each harmonic. To design this high efficiency mode amplifier it should be taken into account a load pull concept based on the study of the desired load impedances at fundamental and harmonic frequencies. Two topologies have been followed: BAR HEAP antenna and E-class heap antenna. The former achieves efficiencies up to 60% with very low bias while the second achieves efficiencies up to 80-85% with larger consumption. A E-class HEAP antenna with a transistor efficiency of about 80 % @ Vcc=12.5, and EIRP=2.1 W has been achieved. Figure

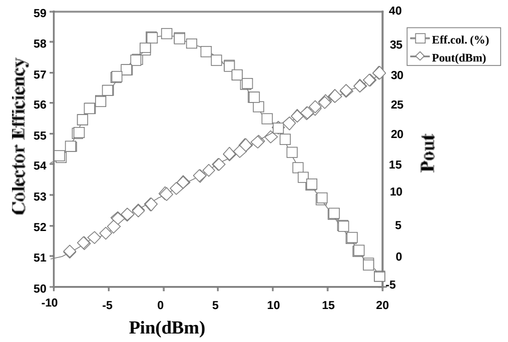

Figure5: Added efficiency in BAR active antenna.

C. Mixing active antenna

From a circuit point of view the integration of a mixer in the antenna will yield to a more compact and simpler receiver or transmitter design. Besides it can also provide a conversion gain if the mixer is based on a FET.

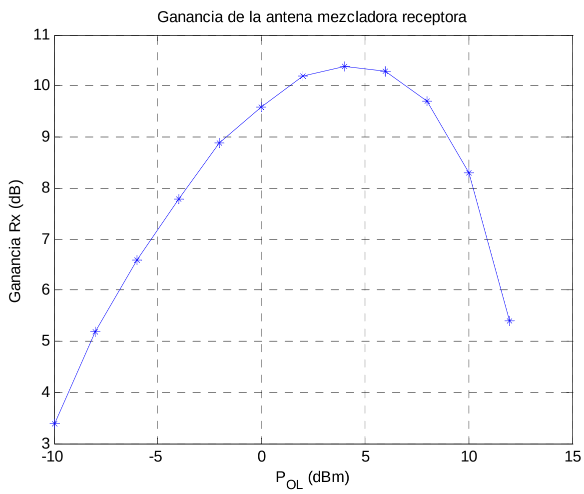

Figure 6: Conversion gain in the active mixing antenna vs P_{LO}

A study of the mixer RF impedance has shown a dependence of the conversion gain on the impedance of the RF port. This study has revealed the existence of optimum impedance for maximum gain conversion. This impedance can be provided by the patch itself resulting in a maximum gain mixing active antenna. This antenna has shown a capacitive behaviour. Lastly, the main drawback of mixing antennas is their low performance in noise limited systems. For that reason the application of the mixing active antenna has been done for an interference limited system.

IV Periodic structures

Periodic structures have shown potential capabilities in the design of new antenna structures: EBG, FSS and metamaterials have shown important features in the design of antenna structures.

A. Frequency selective surfaces

Frequency Selective Surfaces's (FSS's) representation with an equivalent circuit composed of lumped elements is very useful in the design stage, where it is desirable to know in a quick way if a FSS is able to give a fixed frequency response.

The final aim will be to obtain an equivalent circuit that fits the simulated FSS response with the proposed LC circuit. The method will be validated with a metallic ring on a dielectric substrate.

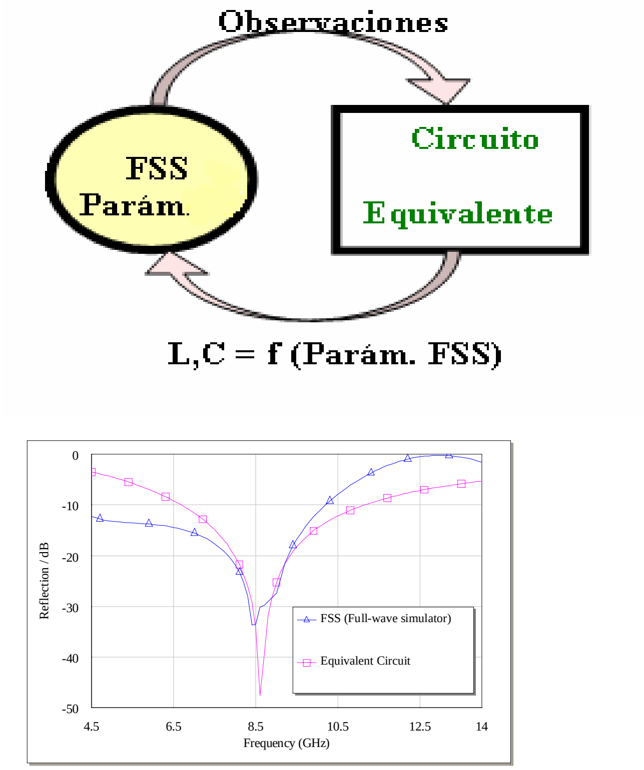

Figure 7: Proposed design model and applications when changes occur from the initial conditions.

B. Metamaterials

Self-diplexed antennas where the transmitter and receiver are directly connected to the antenna can be another way of active antenna where you reduce drastically the losses associated to all the connective circuits and transmission lines. Using metamaterials or Composite Right/Left Handed (CRLH) Transmission Lines (TL) makes possible the construction of a diplexer that could separate the transmitting and receiving frequencies. The block diagram is shown in figure 8:

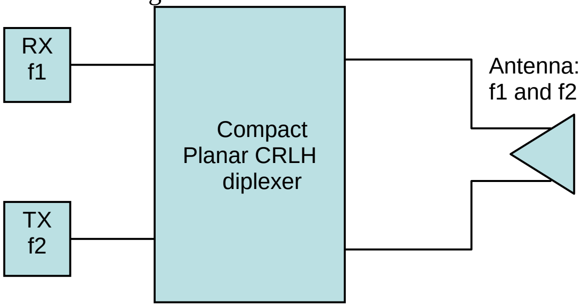

Figure 8: Self-diplexed antenna based on CRLH lines

This diplexer consists of a dual frequency double rat-race that interchanges the isolated ports at two working frequencies. The dual frequency double rat-race requires that the phase delay of two lines must be opposite while the phase delay of the other two lines must be equal at the working frequencies. This arbitrary phase control has to be done with CRLH lines what makes possible interchange the isolated ports. Besides, a planar topology is also preserved. As an example of application, a 950 MHz/1.8 GHz diplexer composed of two dual frequency double rat race hybrids is shown.

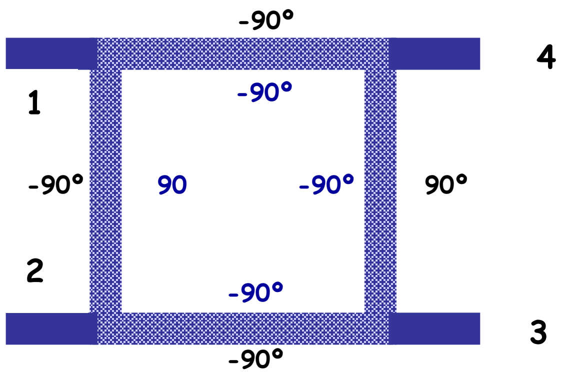

Figure 9: Diagram of the diplexer: The inner legend shows the rat-race at one frequency while the outer one shows the other one

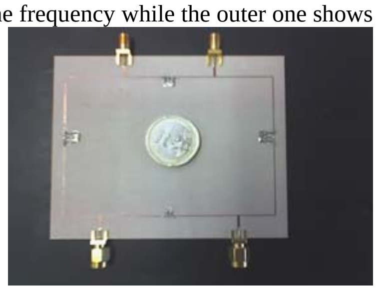

Figure 10: Photograph of the proposed diplexer

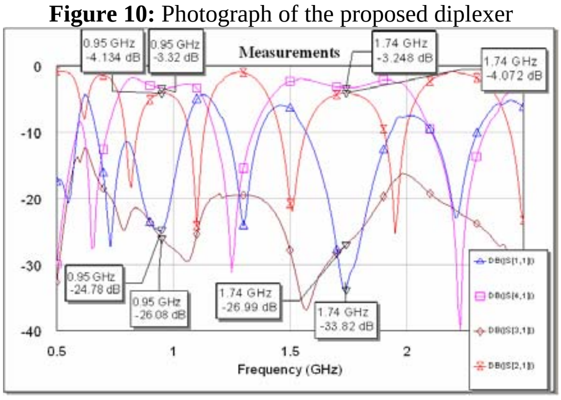

Figure 11: Measurements of the proposed diplexer

V Adaptive Antennas

Two lines have been followed in adaptive antennas: robust algorithms with low computational cost and algorithms for reducing the effect of mutual coupling. The presence of mutual coupling severely degrades the performance of an adaptive array. A simple method based on obtaining an $(N\times N)$ coupling matrix, C, to compensate the coupling effects in direction of arrival (DOA) estimation algorithms is presented. It is based on the theory of characteristic modes in conjunction with an element-by-element analysis of finite arrays. As a small number of characteristic modes are needed to yield a good approximation of induced currents, the method reduces significantly the computational effort in calculating the unknowns. Its application to the MUSIC algorithm results in good and efficient performance.

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