José María Lopetegui Beregaña nació en Pamplona el 16 de agosto de 1973. Es Ingeniero de Telecomunicación por la Universidad Pública de Navarra desde 1997 y Doctor Ingeniero de Telecomunicación por la misma universidad desde 2002 con su tesis doctoral titulada "*Photonic Bandgap structures in microstrip technology: Study usinf the coupled mode formalism and applications*". Entre 1997 y 1999 trabajó como Profesor Asociado en el Departamento de Ingeniería Eléctrica y Electrónica de la Universidad Pública de Navarra. Posteriormente, entre 1999 y 2000, disfrutó de una beca predoctoral de la Universidad Pública de Navarra y finalmente de una beca de Formación de Personal Investigador del Ministerio de Educación y Cultura. Desde octubre de 2000 y hasta la actualidad, trabaja en el Departamento de Ingeniería Eléctrica y Electrónica de la Universidad Pública de Navarra, primero como Ayudante de Escuela Universitaria y posteriormente, desde 2003, como Profesor Ayudante Doctor, donde imparte docencia en el área de Teoría de la Señal y Comunicaciones. Entre los años 2002 y 2003 realizó una estancia post-doctoral en el centro europeo de tecnologías e investigación espaciales (ESTEC) de la Agencia Espacial Europea (ESA) en Holanda, desarrollando aplicaciones para comunicaciones por satélite de las estructuras *Photonic Bandgap* en el rango de microondas estudiadas en su tesis.

Sus intereses de investigación actuales incluyen los metamateriales y sus aplicaciones para microondas y ondas milimétricas (en particular las estructuras *Photonic Bandgap*, las de índice de refracción negativo o *Left Handed Media*, y los *Split Ring Resonators*), así como la teoría de acoplo de modos, y las técnicas de síntesis utilizando *Inverse Scattering*.

Resumen de la Tesis Doctoral:

Photonic Bandgap Structures in Microstrip Technology: Study Using the Coupled Mode Formalism and Applications

Realizada por **José María Lopetegui Beregaña**
en el Departamento de Ingeniería Eléctrica y Electrónica
de la Universidad Pública de Navarra

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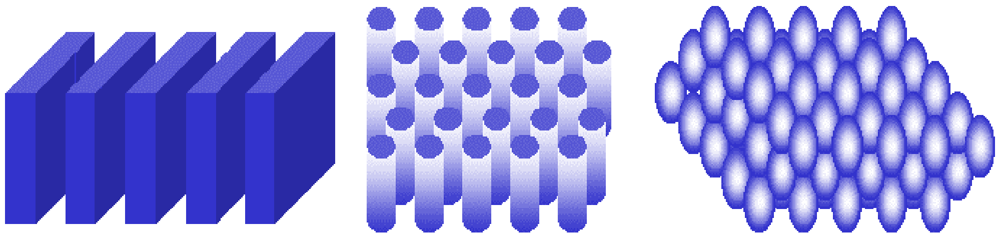
1. Background

In the last years the field of periodic structures for electromagnetic waves has received an important impulse with the introduction of the novel and fruitful concepts of Photonic Bandgap (PBG) and Photonic/Electromagnetic Crystal. These novel concepts were originally developed by Yablonovitch [YAB 87] and John [JOH 87] in the latest 1980s, in the optical wavelength region. The idea was to design materials so that they can affect the properties of photons, in much the same way that ordinary semiconductor crystals affect the properties of electrons. Both Yablonovitch and John suggested that structures with periodic variations in dielectric constant, resembling the self-organized structure of atoms in a semiconductor, could influence the nature of photonic modes in a material, creating forbidden frequency bands in certain directions (partial photonic bandgaps) or in all the directions (complete photonic bandgaps). These new materials were called Photonic Crystals or Photonic Bandgap (PBG) Crystals. Figure 1 shows schematics of Photonic Crystals with one-dimensional (1D), two-dimensional (2D), and three-dimensional (3D) periodic variations of the dielectric constant.



(*a*) (*b*) (*c*)

Figure 1: *Photonic Crystals or Photonic Bandgap (PBG) Crystals showing periodicity in several dimensions. From left to right, (a) one-dimensional (1D), (b) two-dimensional (2D), and (c) three-dimensional (3D) periodic arrangements of implants of a dielectric constant (or refractive index) embedded in a host with another dielectric constant.*

This way, PBG crystals can be defined as one- two- or three-dimensional periodic structures in which the propagation of electromagnetic waves is not allowed in some frequency bands or directions, behaving in a similar way as electronic crystals (e. g. semiconductors) do for the flow of electrons [JOA 95]. Their operation rely, however, on the well-known Bragg reflection effect, but in this case one- two- or three-dimensional periodic structures can be involved, and hence the term ‘generalized Bragg reflection’ is sometimes used.

Of special importance to establish and extend the knowledge on these novel concepts and materials was the edition of ‘Photonic Crystals’, by Joannopoulos et al. [JOA 95]. It was the first book entirely devoted to the topic, and it is indeed a very valuable reference.

Although the research was initially focused on the optical wavelength region, PBG crystals and properties are scalable and applicable to a wide frequency range. This happens because Maxwell’s equations have no fundamental length scale. Actually, the implications for the microwave and millimeter wave domains became soon apparent and multiple interesting and promising structures and applications were developed.

It is worth saying that far from the optical frequency range, ‘*Photonic* Crystal’ could be an ambiguous term, and the denomination ‘*Electromagnetic* Crystal’ seems to be natural and has been also proposed at those non-optical frequency ranges. However, and although it was somehow controversial, they are also frequently termed simply as PBG (i.e. *Photonic* Bandgap) structures, regardless of the frequency regime of operation. Here, '*Photonic*' should be understood neither with the meaning of referring to optical frequencies, nor considered as underlining any kind of process related to the wave-particle duality. Here, '*Photonic*' only enhances the relationship of all these structures with those in the optical range where they first appeared, as well as, owing to the scaling property of the solution of Maxwell's equations, it makes apparent that many concepts and ideas developed for them in the optical range can be directly transposed to other frequency ranges. Additionally the term '*Photonic* Crystal' reminds the fact that a fruitful analogy can be established between the operation of these structures and the way in which ordinary semiconductor crystals affect the properties of electrons.

Specially significant from the point of view of nomenclature in the framework of this thesis is the term employed by the pioneers in the introduction of PBG structures in microstrip circuits and in their applications. This pioneering and leading role has been carried out by Prof. Tatsuo Itoh and his group at the University of California in Los Angeles, using the term 'PBG structure'.

PBG structures at microwave frequencies were initially realized by scaling the structures used at optical frequencies. That implied micromachining holes into dielectric slabs to create a 2D [GAU 97] periodic variation of the material dielectric constant. Machined slabs could be also stacked to create a 3D periodic variation of the dielectric constant [SMI 99]. Specially famous is the 'woodpile' structure, Fig. 2, a layer-by-layer PBG crystal made of stacked alumina rods, of the Iowa State University [HO 94, OZB 96].

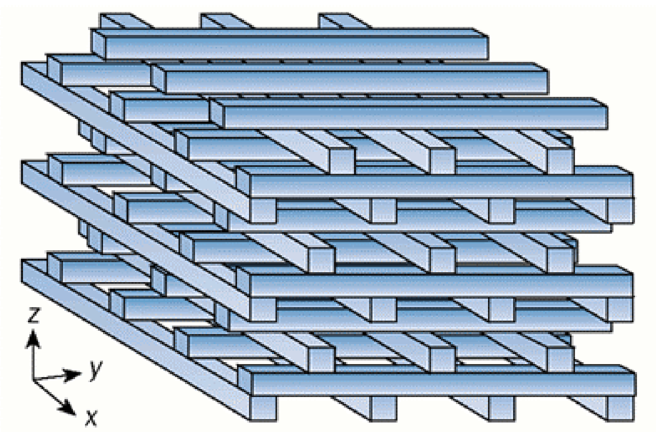


Figure 2: *The 'woodpile' 3D PBG crystal made by stacking alumina rods*

The main applications proposed for these microwave PBG structures were their use as substrates for planar antennas (to improve their efficiency and radiation pattern by forbidding surface wave excitation) [GAU 97, SMI 99] the implementation of reflectors (since they provide wide and deep reflected frequency bands) [KES 96], and the implementation of resonant cavities and waveguides [TEM 99].

However these configurations, while useful, have two main drawbacks: firstly, they are not easy to fabricate and, secondly, they are big in terms of wavelength. To reduce the PBG crystal dimensions the use of metallodielectric configurations was proposed [BRO 95, FAN 96, SIE 98]. An effective example of metallodielectric crystal is given by the high-impedance ground plane described in [SIE 98a], and employed to improve a patch antenna performance in [QIA 98]. It is comprised of a grounded dielectric slab periodically loaded with a square lattice of square metallic pads. The edges of the pads are a few millimeters apart, realizing a 2D periodic network of capacitors. Each pad is connected to the ground through one via at its center, which provides the inductive part of the LC-network.

These approaches, although very effective, require a non-planar fabrication process. In the latest 1990s, Prof. Tatsuo Itoh's group at the University of California in Los Angeles, focused on the development of planar PBG crystals that do not need vias and that can be easily integrated in conventional planar microwave and millimeter-wave circuits. His achievements constituted a real breakthrough in the application of PBG structures in the microwave and millimeter wave filed, since the planar circuit technology is the driving force for modern microwave and millimeter wave applications, because of its enormous advantages including greatly reduced hardware size and weight, lower profile, easier integration with solid state devices, low power consumption, conformal implementation on moving platforms, and greatly reduced fabrication cost because they can be simply printed on a circuit board or semiconductor wafer in large quantities instead of being machined piece by piece. However, one of the fundamental disadvantages of planar circuits when used at high frequencies is their relatively high loss or low quality factor (Q), in comparison to the classical and bulky metallic waveguide systems. It is therefore extremely interesting to explore novel ideas, concepts and structures, like the PBG crystals, to try to improve the performance of planar microwave and millimeter wave systems. Actually, this thesis will be devoted specifically to the study PBG structures in the most popular microwave planar circuit technology: the microstrip technology.

The first approach proposed by Prof. Itoh to produce a PBG structure in microstrip technology consisted in drilling a periodic pattern of cylinders in the substrate of the microstrip line to locate implants of different materials within them, or to leave them filled by air [QIA 97]. A photograph of a prototype is shown in Fig. 3. However, it was soon found that PBG structures with even deeper and wider stopbands could be simply achieved by etching a periodic pattern of circles in the ground plane along the microstrip line. This approach is simpler to fabricate, compatible with the monolithic technology, and permits the PBG structure to be integrated with other microstrip components in the upper plane. As a first approximation, a PBG microstrip structure with three rows of same-size and equidistant circles, one of them etched in the ground

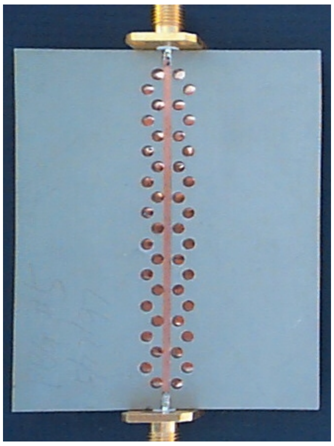
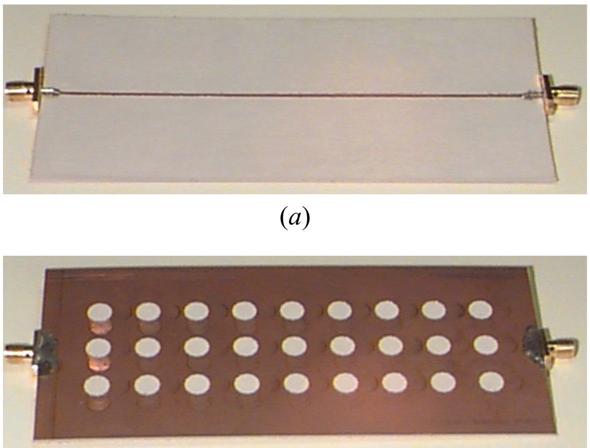


Figure 3: *PBG crystal in microstrip technology obtained by drilling a periodic pattern in the dielectric substrate, as it was originally proposed by Prof. Itoh at UCLA.*
(Source: http://www.cwc.nus.edu.sg/news/seminar/arch1.shtml, speaker's notes on 'Photonic Bandgap structures for microwave circuits', by Dr A. Alphones at the Center for Wireless Communications, National University of Singapore).

plane just below the upper-plane conductor strip and the two others at both sides of it, was designed [RAD 98]. A photograph of a prototype is shown in Fig. 4.

An also very interesting PBG structure for planar microwave circuits was later proposed. It is a more compact crystal referred to as Uniplanar Compact PBG (UC-PBG) structure, which realizes a 2D periodic network of LC circuits without introducing vias. It is also very attractive for applications to MICs and MMICs because of the easy and low cost realization as well as compatibility with standard fabrication techniques, although the rejection level provided by it in the forbidden band is not as predictable and regular as in the previous structures [QIA 98a, YAN 98]. A sketch of the PBG crystal structure can be seen in Fig. 5.

The range of applications proposed for these PBG structures in microstrip technology in the last years has been very wide. Among them we can include broadband harmonic tuning in power amplifiers [RAD 98a, RAD 98b, RAD 98c, HAN 99, YOO 01], oscillators [XUE 01] and mixers [YAN 99a], to increase the output power and the efficiency, and to reduce the spurious harmonics of these active devices; the implementation of microstrip lowpass filters with a wide high-frequency rejection bandwidth [RUM 98, YAN 99a, KIM 00]; the implementation of



(*a*)

(*b*)

Figure 4: *PBG crystal in microstrip technology obtained by etching a 2D lattice of holes in the ground plane (b), while the upper plane is unperturbed (a), as it was originally proposed by Prof. Itoh at UCLA. The photograph shows a prototype fabricated at the Public University of Navarre, Spain.*

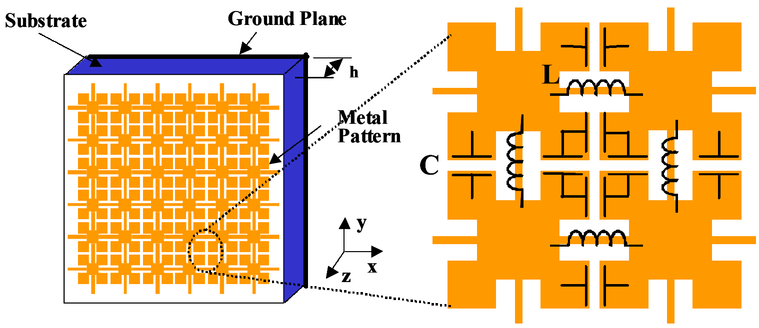


Figure 5: *Uniplanar Compact PBG (UC-PBG) structure proposed by Prof. Itoh at UCLA. This more compact crystal realizes a 2D periodic network of LC circuits without introducing vias, as it is shown in the sketch.*
(Source: http://www.cwc.nus.edu.sg/news/seminar/arch1.shtml, speaker's notes on 'Photonic Bandgap structures for microwave circuits', by Dr A. Alphones at the Center for Wireless Communications, National University of Singapore).

microstrip bandpass filters with intrinsic spurious suppression [YAN 98a, YAN 99, YAN 00, JI 00]; and suppression of radiation at harmonic frequencies in microstrip patch antennas with PBG ground plane [HOR 99], or reduction of their power losses and improvement of their radiation pattern and efficiency due to the inhibition of surface wave excitation [COC 98, COC 99].

Other more sophisticated applications that are also interesting to mention include the reduction of parallel-plate mode leakage in conductor-backed coplanar waveguide and in stripline [MA 98, MA 99, YAN 99], the suppression of the coupling between adjacent microstrip lines [LEO 02], and the implementation of TEM waveguides [YAN 99b]. It is also interesting to note that other different periodic patterns have been proposed by several groups to implement PBG crystals in microstrip technology [XUE 00, KIM 00a], and even PBG structures for coplanar waveguides have been lately proposed [FU 01].

Actually, the topic of PBG structures for planar microwave circuits (particularly microstrip circuits) has attracted an increasing interest among the researchers in the last years, that has led to an important number of journal articles devoted to them, and to the introduction of sections dedicated to the topic in the latest books about microstrip technology that have been published [EDW 00, HON 01, ITO 01]. It can be said that the topic is growing very quickly and becoming quite popular in the microwave planar circuit community, due to the promising and exciting applications envisaged. However, the new terminology, concepts, ideas and applications must not fade the fact that these devices are intimately related to the historically known microwave and millimeter wave periodic structures [COL 91]. In fact, microwave applications of periodic structures can be dated back to the early days of radar, with such examples as one-dimensional (1-D) slotted-waveguide array antennas, as well as two-dimensional (2-D) frequency selective surfaces (FSSs) and polarization diplexers. The emphasis of recent research efforts, however, is on 1-D or 2-D PBG structures that are compatible with modern planar circuit fabrication technology. Applying the PBG concept allows one to greatly extend the horizon of imagination when conceiving novel structures to control the behavior of electromagnetic waves, whether it is a guided wave, surface wave, or radiation wave. For example, as it has been previously commented, microstrip-based lowpass (rejected band) filters can be achieved applying the PBG concept by modifying the dielectric substrate [QIA 97] and/or the ground plane [RAD 98, YAN 99], rather than following the traditional high-low impedance line approach. In the same way, applying the PBG concept, surface wave and leaky wave suppression can be achieved by the same means.

2. Main contributions of the thesis

The work presented in this thesis is focused on the study of PBG structures in microstrip technology for circuit applications. The starting point will be the PBG structure for microstrip lines proposed by Prof. Itoh in 1998, and obtained by etching a periodic pattern of circles, following a square lattice, in the ground plane of a microstrip line (see Fig. 4) [RAD 98]. The frequency response of this structure was very promising, since it included a low-loss passband, together with a wide and deep rejected band whose central frequency is fixed by the periodicity of the perturbation. However, the analysis and design of the structure was troublesome, since it features a ground plane perturbation of distributed nature, that is difficult to fit in the models customarily employed to analyze microwave periodic structures. Actually, the analysis and design of these devices was carried out with no more tools than time-consuming full-wave electromagnetic simulations, and a trial method was used to adjust the structure parameters to satisfy the required specifications. In order to surpass these difficulties, and to have a better insight into the operation of the structure, a very convenient way to model Photonic Bandgap structures for planar microwave and millimeter wave circuits that suits very well distributed perturbations is proposed: the use of the coupled mode theory. Here we have applied it to PBG structures in microstrip technology, but it could be easily extended to other planar waveguides.

In order to formulate an accurate coupled mode theory suitable for microwave and millimeter wave devices, the cross-section method was used in the chapter 2 of this thesis. The basic idea of the cross-section method is that the electromagnetic fields at any cross section of a nonuniform waveguide can be represented as a superposition of the forward and backward travelling waves associated to the different modes of an auxiliary uniform waveguide that has the same cross section and identical distribution of ε and μ as the considered cross section. The coefficients of this superposition can be seen as the complex amplitudes of the modes along the nonuniform waveguide, and satisfy a set of first order linear ordinary differential equations, that turn into integro-differential equations for open waveguides, known as the coupled mode equations. In this way, the general problem of field derivation in a nonuniform waveguide (i.e. the three-dimensional (3D) electromagnetic problem) is reduced to the two-dimensional (2D) problem of mode field calculation in a uniform waveguide, and to the one-dimensional problem (1D) of solution of the coupled mode equations.

The method was rigorously applied to analyze open waveguides that can include metals, and in particular perturbed ground planes and strip conductors, covering all of our cases of interest. As a result of it, the system of coupled mode equations that characterizes the nonuniform waveguide of interest was obtained. The system includes the discrete and the continuous spectrum modes, and takes into account all the phenomena (including the radiation), with no approximation involved.

The expansion of the fields realized is the following:

$$\hat{\vec{E}}(x,y,z) = \sum_{i=-M}^{M} a_i(z)\cdot\vec{E}^i(x,y,z) + \sum_{i=-Q}^{Q}\int_0^\infty a_i(k_t,z)\cdot\vec{E}^i(x,y,k_t,z)\cdot dk_t$$

$$\hat{\vec{H}}(x,y,z) = \sum_{i=-M}^{M} a_i(z)\cdot\vec{H}^i(x,y,z) + \sum_{i=-Q}^{Q}\int_0^\infty a_i(k_t,z)\cdot\vec{H}^i(x,y,k_t,z)\cdot dk_t$$

and the coupled mode equations obtained are:

$$\frac{da_m}{dz} + j\cdot\beta_m\cdot a_m = \sum_{i=-M}^{M} a_i\cdot C_{mi} + \sum_{i=-Q}^{Q}\int_0^\infty a_i(k_t)\cdot C_{mi}(k_t)\cdot dk_t$$

$$\frac{da_n(\widetilde{k}_t)}{dz} + j\cdot\beta_n(\widetilde{k}_t)\cdot a_n(\widetilde{k}_t) = \sum_{i=-M}^{M} a_i\cdot C_{ni}^c(\widetilde{k}_t) + \sum_{i=-Q}^{Q}\int_0^\infty a_i(k_t)\cdot C_{ni}^c(\widetilde{k}_t,k_t)\cdot dk_t$$

Finally, the expression for the coupling coefficient obtained for our case of interest of a microstrip line with a perturbed ground plane is:

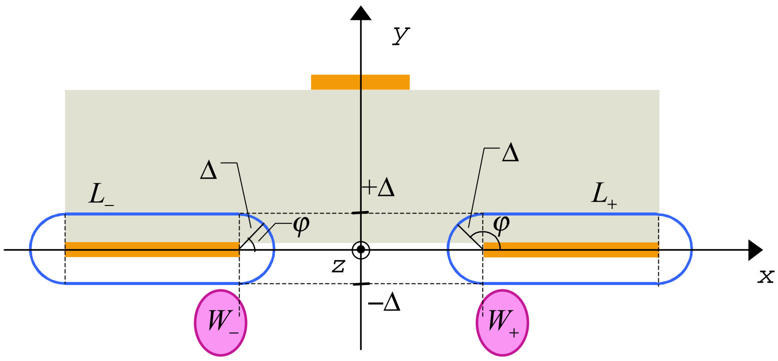


Figure 6: *Front view of a microstrip line with a pattern etched in the ground plane, showing the integration paths, L_+, L_-, in blue color, for the coupling coefficient expression.*

$$C_{mi} = \frac{-\omega}{2 \cdot N_m \cdot (\beta_m - \beta_i)} \cdot \left[\frac{dW_+}{dz} \cdot \lim_{\Delta \to 0} \int_{3\pi/2}^{\pi/2} F_{mi}(W_+ + \Delta \cdot \cos(\varphi), \Delta \cdot \sin(\varphi), z) \cdot \Delta \cdot d\varphi + \right.$$

$$\left. + \frac{dW_-}{dz} \cdot \lim_{\Delta \to 0} \int_{\pi/2}^{-\pi/2} F_{mi}(W_- + \Delta \cdot \cos(\varphi), \Delta \cdot \sin(\varphi), z) \cdot \Delta \cdot d\varphi \right]$$

where

$$F_{mi}(x,y,z) = \mu_0 \cdot H_z^i \cdot H_z^m - \mu_0 \cdot H_t^i \cdot H_t^m + \varepsilon_1 \cdot E_n^i \cdot E_n^m$$

and the variables and integration paths are represented in the drawing of Figure 6.
It is interesting to remark that there are no approximations involved in these expressions.

However, as it is explained in the chapter 3 of the thesis, the problem can be notably simplified by realizing several reasonable approximations that will eventually lead to a simplified system of coupled mode equations that allows us to obtain a fast numerical solution of the general problem, and that features analytical solutions for the case of uniform PBG structures. In this way, a comprehensive set of analytical expressions for the most important design parameters of PBG microstrip structures will be furnished. The set of analytical expressions available cover a wide scope, ranging from the S parameters to the Bloch wave analysis, and constitutes a very useful and unique set of tools for the analysis and design of these devices.
The reasonable approximations introduced to obtain the simplified system of coupled mode equations valid for PBG structures for microstrip lines are:

- We are going to neglect the coupling of energy to the modes of the continuous spectrum. This can be done because the energy of these modes is primarily radiated, and since the devices that we are going to study (filters, resonators, ..) have very little radiation losses in the frequency bands of interest, the error involved in the approximation will be small.
- Regarding the modes of the discrete part of the spectrum, for the frequency band of interest we will only have the quasi-TEM mode for the sections of pure microstrip line, and a quasi-microstrip mode together with a quasi-slot mode for the sections of microstrip with slot in the ground plane that appear due to the introduction of the PBG structure. There will be no higher order modes due to the frequency band of interest and to the thickness of the substrate employed, in the same way as it would happen for a pure microstrip line. Since the excitation of the devices under study will be done through a pure microstrip line, the

excitation mode will be always the quasi-TEM mode of the microstrip line (fundamental microstrip mode). This mode has very high correlation with the quasi-microstrip mode (actually it can be seen as the same mode), and very low correlation with the quasi-slot mode, so we can approximate neglecting the excitation of the quasi-slot mode and assuming that only the quasi-microstrip mode is excited.

These approximations lead us to assume single mode operation in our PBG structure for microstrip lines, and in this way they significantly simplify the coupled mode equations. With them, we have to take into account only one mode (the fundamental microstrip or quasi-microstrip mode), with two associated waves: the forward and backward travelling waves, and the system of coupled equations simplifies to:

$$\frac{da^+}{dz} + j \cdot \beta \cdot a^+ = a^- \cdot K$$

$$\frac{da^-}{dz} - j \cdot \beta \cdot a^- = a^+ \cdot K$$

In the same way it is demonstrated that the coupling coefficient can be approximated by:

$$K(z) = \frac{1}{2} \cdot \frac{1}{Z_0} \cdot \frac{dZ_0}{dz}$$

and therefore a quick numerical solution of the general problem can be obtained.
Additionally, for the common case of uniform (fully periodic) PBG structures, approximate analytical solutions have been obtained. To get them two new approximations have been employed:

- We approximate the phase constant β (and hence the effective dielectric constant ε_{eff}) as a variable constant with z. This approximation involves the election of an "averaged" β (and ε_{eff}) for the device under study. It is demonstrated that the most appropriate value for it is:

$$\beta(z,f) = \frac{2 \cdot \pi \cdot f}{c} \cdot \sqrt{\varepsilon_{eff}(z,f)} \qquad ; \qquad \varepsilon_{eff} = \left(\frac{1}{\Lambda} \cdot \int_0^{\Lambda} \sqrt{\varepsilon_{eff}(z)} \cdot dz \right)^2$$

- Due to the fact that the PBG structure for microstrip lines will be periodic along the z direction with period Λ, the coupling coefficient, $K(z)$, will be periodic with the same period, and hence it will be amenable to be expanded in a Fourier series. We select one rejected band as the Bandgap of interest (the n-th rejected frequency band), and in this way, we take only the corresponding term of the Fourier series of $K(z)$:

$$K(z) = \sum_{n=-\infty}^{n=\infty} K_n \cdot e^{j \cdot \frac{2\pi}{\Lambda} \cdot n \cdot z} \qquad ; \qquad k = j \cdot K_n$$

Consequently it is demonstrated that for the frequency range around the n-th rejected frequency band, the coupled mode equations of the PBG structure in microstrip technology can be approximated in the following way:

$$\frac{dA^+}{dz} = j \cdot k^* \cdot e^{j \cdot 2 \cdot \Delta\beta \cdot z} \cdot A^- \qquad ; \qquad \Delta\beta = \beta - n \cdot \frac{\pi}{\Lambda}$$
$$\frac{dA^-}{dz} = -j \cdot k \cdot e^{-j \cdot 2 \cdot \Delta\beta \cdot z} \cdot A^+$$

and this simplified system of coupled mode equations features analytical solution.
From the analytical solution, a set of analytical expressions for the most important design parameters of the PBG structure in microstrip technology are obtained, including the *S* parameters, frequency of maximum attenuation, value of the maximum attenuation, rejected bandwidth, transmission matrix:

$$S_{11} = \frac{k \cdot \sinh(\gamma \cdot L)}{-\Delta\beta \cdot \sinh(\gamma \cdot L) + j \cdot \gamma \cdot \cosh(\gamma \cdot L))} \quad ; \quad S_{21} = \frac{j \cdot \gamma \cdot e^{-j \cdot \frac{\pi}{\Lambda} \cdot n \cdot L}}{-\Delta\beta \cdot \sinh(\gamma \cdot L) + j \cdot \gamma \cdot \cosh(\gamma \cdot L)}$$

$$f_{max} = n \cdot \frac{c}{2 \cdot \sqrt{\varepsilon_{eff}} \cdot \Lambda} \quad ; \quad \left|S_{21}\right|_{min} = \mathrm{sech}(|k| \cdot L) \quad ; \quad BW_\infty = \frac{c \cdot |k|}{\pi \cdot \sqrt{\varepsilon_{eff}}} \cdot \sqrt{1 + \left(\frac{\pi}{|k| \cdot L}\right)^2}$$

$$A_{11} = \left(\cosh(\gamma \cdot L) + \frac{j \cdot \Delta\beta \cdot L \cdot \sinh(\gamma \cdot L)}{\gamma \cdot L}\right) \cdot e^{j \cdot \frac{\pi}{\Lambda} \cdot n \cdot L} \quad ; \quad A_{21} = \frac{j \cdot k \cdot L \cdot \sinh(\gamma \cdot L)}{\gamma \cdot L} \cdot e^{j \cdot \frac{\pi}{\Lambda} \cdot n \cdot L}$$

and even the Bloch wave analysis parameters: dispersion diagram and Bloch wave characteristic impedance.
These analytical expressions have been tested in several PBG prototypes in microstrip technology, both in simulations and measurements, showing very high accuracy and demonstrating that they constitute a very useful and unique set of tools for the analysis and design of these PBG devices.
To finish the theoretical part of the thesis a relation between the coupling coefficient of the PBG structure, *K(z)*, and its reflection parameter, $S_{11}(f)$, is obtained in terms of Fourier transforms. The approximate expression for structures with low reflectivity reveals that the Fourier transform of the coupling coefficient is equal to the reflection parameter, while the general expression valid also for high reflectivity has the form of a series that includes additional terms.

It is interesting to note that a system of coupled mode equations identical to the last one is also obtained when a uniform Fiber Bragg Grating or a uniform optical periodic dielectric waveguide is studied by using the coupled mode theory [PAS 96, YAR 97, YAR 84]. However, the starting point to obtain the equations is different from the one that we have used for PBG structures in microstrip technology.
In the case of Fiber Bragg Gratings, the longitudinal perturbation introduced in the refraction index is very small, and therefore we can approximate assuming that the longitudinal perturbation doesn't alter the *(x,y)* dependent part of the fields of the mode, nor its phase constant, and it only affects the amplitude of the associated wave and hence the power carried.
The approach taken assumes that the fields in a cross section of the perturbed optical fiber can be represented as a superposition of the modes of the unperturbed optical fiber. The amplitude of the waves associated to these modes will be variable with *z* though. This approach is referred

to in [MAR 91] as "expansion in terms of ideal modes", while the approach that we use to model PBG structures for microstrip lines (the cross section method) is referred to as "expansion in terms of local normal modes".
It is worth noting that the expansion in terms of ideal modes is very good for the case of Fiber Bragg Gratings because the perturbation present in the optical fiber is very small, but it wouldn't be suitable for PBG´s in microstrip technology. In the PBG case, the perturbation introduced is so strong that the modes of the unperturbed structure can no longer be taken as a base to expand the fields in all the perturbed structure, but different modes must be taken for different cross sections.
However, the fact that the simplified equations that govern the behavior of both kind of devices are the same suggests that a lot of ideas and techniques employed in the developed and mature field of Fiber Bragg Gratings could be easily and successfully translated to the novel and emerging field of PBG structures for planar microwave and millimeter wave circuits.
The study of PBG structures in microstrip technology using the coupled mode theory provides also physical insight about the operation of the structure, and reveals a direct and fruitful link with the well established topic of Fiber Bragg Gratings (FBGs) in the optical regime. As a consequence, several ideas and techniques that are widely employed in the field of FBGs, can be transposed to the novel and emergent field of PBG structures for microstrip lines, to improve their performance. In this way, in the chapter 4 of this thesis, optimization techniques to enhance the performance of PBG structures in microstrip technology are proposed and tested. The results obtained are very satisfactory.
The frequency response of a PBG structure in microstrip technology features a wide rejected band whose central frequency is fixed by the periodicity of the periodic perturbation. However, the frequency response of a conventional PBG device includes also characteristics that can be detrimental in many applications: an important ripple appears in the passbands placed to the left and to the right of the rejected band; sometimes a wider rejected bandwidth can be needed; for some applications the circuit area required to implement the PBG structure can be too large; and for other applications the periodicity present in the frequency response (rejected bands at the harmonics of the design frequency) can be troublesome. As it has been commented, in the chapter 4 of this thesis several techniques that allow us to surpass this potential problems are proposed and successfully tested, giving rise to improved PBG microstrip structures.
In Figure 4, the upper plane and the ground plane of a PBG microstrip prototype as originally proposed by Professor Itoh at the University of California in Los Angeles (UCLA) [RAD 98]

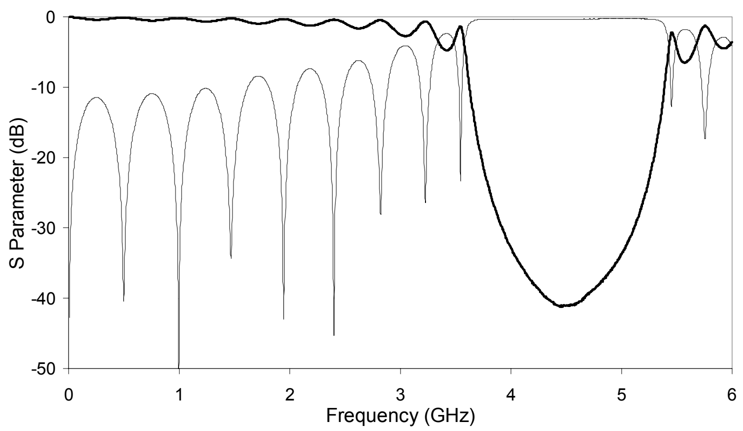


Figure 7: *Measured S_{11} (thin line) and S_{21} (thick line) parameters for the PBG microstrip prototype shown in the photographs of Fig. 4. It has been designed as originally proposed by Prof. Itoh at UCLA.*

was shown. As it has been previously commented this prototype was the starting point of my work in this thesis. Its frequency response is given in Figure 7.
An overview of the optimization techniques proposed in this thesis to obtain improved PBG microstrip structures is shown in Figure 8 and Figure 9.

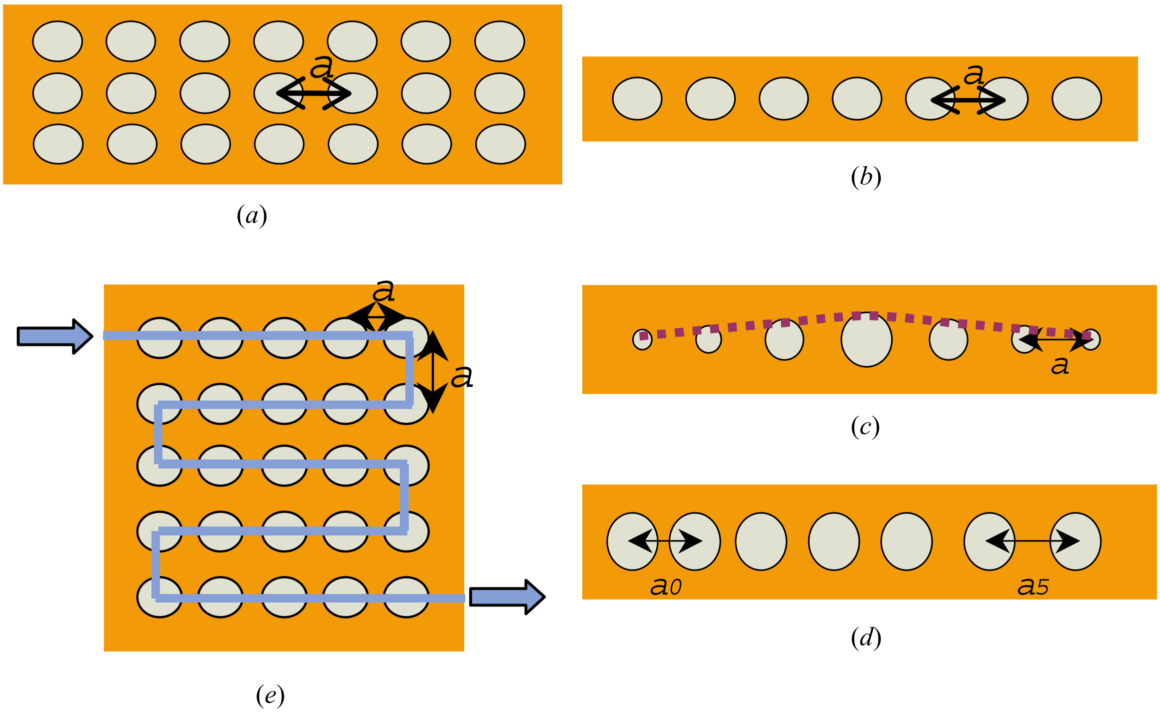


Figure 8: *Schematic representation of the optimization techniques proposed to obtain improved PBG microstrip structures. (a) Original PBG microstrip structure as proposed by Prof. Itoh, (b) 1-D PBG microstrip structure, (c) Tapering techniques, (d) Chirping techniques, (e) Meandering techniques*

The initial periodic patterns proposed to implement PBG structures for microstrip lines were two dimensional (Fig. 8(*a*)). However, the operation of the resulting PBG microstrip circuit was 1D effective, since only the periodicity along the longitudinal dimension of the conductor strip was used. Moreover, due to the high confinement of the fields around the conductor strip of the microstrip line, the field levels outside the central row of circles of the periodic pattern will be very low. Finite Element three dimensional electromagnetic simulation of the PBG structure with two dimensional pattern confirms this fact, and reveals that field levels at the outer rows of the periodic pattern are negligible. This suggests that PBG microstrip structures consisting of only the central row of the pattern (1D) (Fig. 8(*b*)) will have similar behaviour as a 2D structures. The advantage of a 1D implementation is a considerable reduction in the transverse size of the device.
As it can be seen in Figure 7, an important ripple appears in the passbands placed to the left and to the right of the rejected band. This can be troublesome in certain practical applications. To suppress it the use of tapering techniques that consist on the application of a tapering (or windowing) function over the circle radii distribution is proposed in this thesis (see Fig. 8(*c*)). In the same way, chirping techniques that consist on a continuous variation of the period along the PBG structure are proposed here to increase the rejected bandwidth for certain applications (see Fig. 8(*d*)). The effect of both techniques can be clearly understood taking into account the Fourier transform relation that exists between the coupling coefficient and the reflection

parameter. Finally, the use of meandering techniques is also proposed as seen in Figure 8(*e*) to obtain very high rejection levels in a compact circuit layout area.
The Fourier transform relation between the coupling coefficient, $K(z)$ (that is approximately proportional to the derivative with z of the etched profile), and the reflection parameter, $S_{11}(f)$, is further exploited to obtain single frequency tuned PBG microstrip structures (using a sinusoidal perturbation, Fig. 9(*b*)) and multiple frequency tuned PBG microstrip structures (using a pattern formed by the addition of multiple sinusoidal perturbations, Fig. 9(*c*)). These novel structures produce one rejected frequency band and multiple rejected frequency bands, respectively, in contrast with the conventional PBG structure (Fig. 9(*a*)) that produces a periodic frequency response.

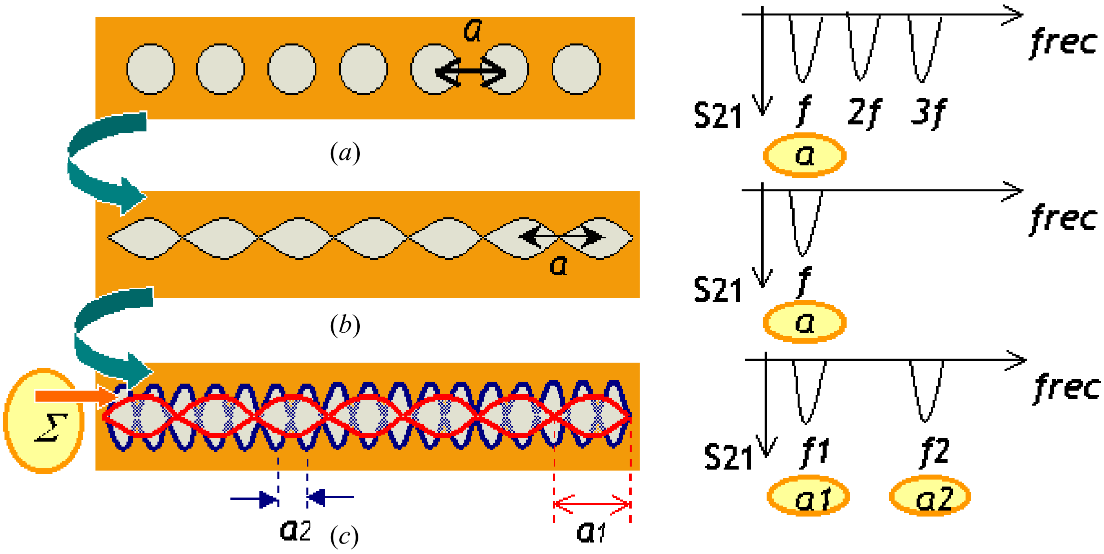


Figure 9: *Schematic representation of the optimization techniques proposed to obtain improved PBG microstrip structures. (a) 1-D PBG microstrip structure, (b) Single frequency tuned PBG microstrip structure, (c) Multiple frequency tuned PBG microstrip structure.*

All of these optimization techniques have been thoroughly tested, both in simulation and in measurement, showing very good performance and constituting very interesting design techniques for a lot of practical applications.

To finish my thesis, in chapter 5 several examples of practical applications of PBG structures in microstrip technology are proposed and tested. The range of applications considered is quite wide, including the suppression of spurious bands and harmonics in passive and active circuits for enhanced out of band behaviour and higher efficiency, the implementation of enhanced lowpass filers and high rejection bandpass filters, the implementation of high-Q fully planar resonators, and the design of chirped delay lines to realize quadratic-phase filters with applications like real-time Fourier analysis. All of the examples presented show successfully the feasibility of the applications proposed and, in general, the high potential of these novel structures. Let's see here some of them. The rest can be found in the thesis.
Spurious passband suppression in passive devices:
In Figure 10, several examples of prototypes of passive devices incorporating PBG structures to suppress spurious passbands are shown. Specifically a lowpass filter (Fig. 10(*a*), Fig 10(*b*)), and a multisection transformer (Fig. 10(*d*), Fig 10(*e*)), with two different PBG profiles are shown.

As it can be seen a very effective rejection of the spurious passband (Fig. 10(*c*)) or of the undesired passband (Fig.10(*f*)) is obtained.

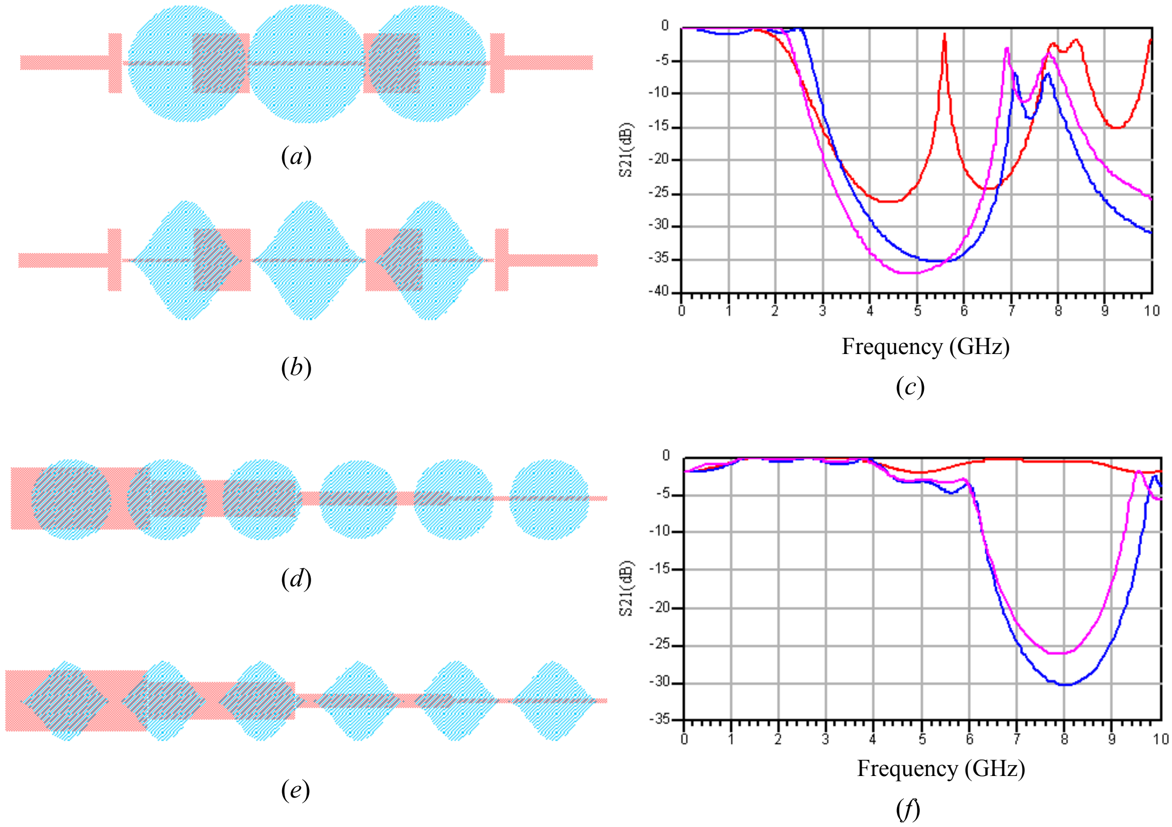
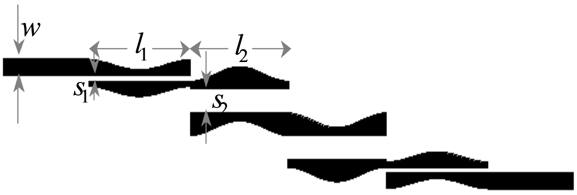
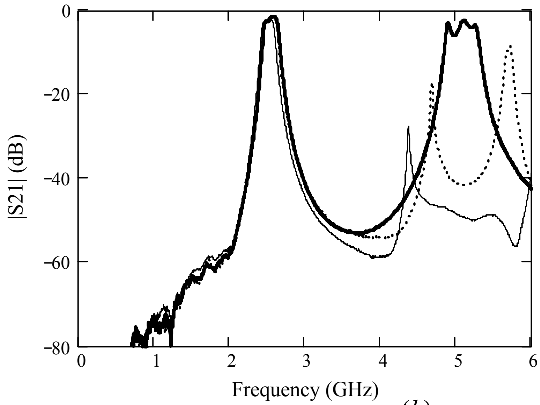


Figure 10: *Sketches of the lowpass filter prototypes with PBG constituted by a discrete pattern of circles (a), and with PBG constituted by a raised-sine pattern (b), and of the multisection transformer prototypes with PBG constituted by a discrete pattern of circles (d), and with PBG constituted by a raised-sine pattern (e). The red parts represent the upper plane conductor strip, and the blue parts represent the area etched in the ground plane.*
The simulated frequency responses for the lowpass filter prototypes (c) and for the multisection transformer prototypes (f), are also given including the conventional prototypes (red line), the prototypes with discrete PBG of circles (blue line), and the prototypes with continuous PBG of raised-sine pattern (pink line)

In Figure 11, the usefulness of some of the concepts developed up to now for PBG microstrip structures is broadened to other classical microstrip circuits. Here, the strip width modulation of otherwise traditionally designed parallel-coupled-line microstrip bandpass filters is proposed in order to suppress their spurious passbands. It is shown that employing a continuous modulation pattern that follows a sinusoidal law, as that previously proposed for the ground plane, the replica of the response at the harmonic of the design frequency can be eliminated, thereafter improving strongly the filter performance, provided that the sinusoidal perturbation period is tuned at the frequency band to reject. Moreover, if the strip width modulation is tuned simultaneously at several sine functions, as in multiple-frequency-tuned PBG microstrip circuits, then several harmonic passbands could be rejected, whenever the sine periods are appropriately tuned at these frequency-bands. This way, these coupled-line microstrip bandpass filters with sine-like modulated strip width have enhanced out-of-band behavior, whilst the main passband is kept virtually unaltered. In Figure 11(*a*) a schematic of the proposed technique is shown together with the frequency response of the optimized filter (Fig. 11(*b*)) compared to that of the conventional filter. A strong rejection of the spurious passband is demonstrated.



(*a*)

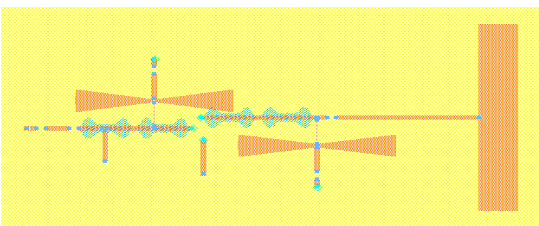


(*b*)

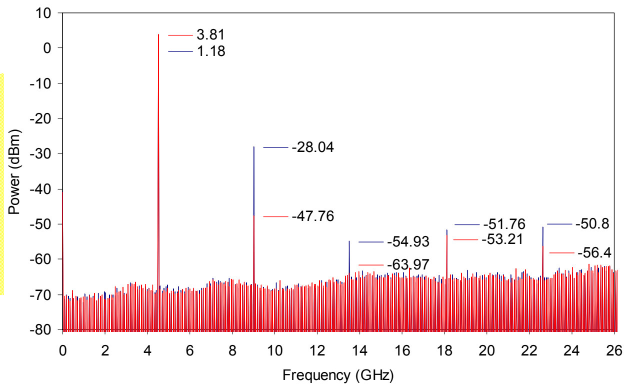
Figure 11: *(a) Schematic of a Wiggly-line bandpass filter resulting after applying the strip width modulation to a classical coupled-line order-3 bandpass microstrip filter, and (b) Measured* S_{21} *parameters for a classical coupled-line order-3 Butterworth bandpass microstrip filter centered at 2.5 GHz with a 10% fractional bandwidth (thick solid line); for a wiggly-line filter with* $M = 37.5\%$ *(dashed line); and for a wiggly-line filter with* $M = 47.5\%$ *(thin solid line).*

<u>Harmonic suppression in active circuits</u>:

Now, the performance of an active antenna in microstrip technology is notably improved by introducing PBG structures produced by etching the ground plane. The active antenna consists of a microwave oscillator directly feeding a patch antenna, and the aim of the PBG structure introduced is to suppress the harmonics present in the radiated power spectrum, increasing at the same time the power level in the fundamental frequency. The PBG structure is tuned to reject the first and the second harmonics. The layout of the prototype is presented in Figure 12(*a*), and its measured power spectrum in Figure 12(*b*). The introduction of the PBG structure is trouble-free, since it does not require a redesign of the circuit, and the circuit layout area needed will be maintained. As it can be seen the radiated power at the fundamental frequency is increased, while a the radiated power at the first and second harmonics is strongly decreased.



(*a*)



(*b*)

Figure 12: *(a) Layout of the active antenna prototype with PBG, designed to operate at 4.5 GHz. The orange parts represent the upper plane conductor strip, and the blue parts represent the area etched in the ground plane, and (b) Measured power spectrum for the classical active antenna (blue line) and for the active antenna with PBG (red line). The frequency dependency of the horn antenna gain is disregarded.*

Méritos especiales que el candidato desea destacar acerca del trabajo de su tesis doctoral

1) Ponencias en congresos y artículos en revistas científicas internacionales con proceso de revisión anónima por pares en los que otros autores citan el trabajo del candidato:

A. B. Abdel-Rahman, A. K. Verma, A. Boutejdar, A. S. Omar, "Control of bandstop response of hi-lo microstrip low-pass filter using slot ground plane," ***IEEE Transactions on Microwave Theory and Techniques***, vol. 52, no. 3, pp. 1008-1013, March 2004.

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A. Görür, C. Karpuz, K. Yalçin, "A novel photonic bandgap (PBG) structure," ***Proceedings of the 31st European Microwave Conference***, September 2001, London, UK, pp. 181-184.

2) Perspectivas de desarrollo industrial de alguno de los trabajos del candidato:

El candidato participa en el proyecto EUREKA 2895 TELEMAC, titulado: ”Estudio y control de la propagación de microondas y de ondas milimétricas por metamateriales”. El consorcio europeo que desarrolla el proyecto está formado por importantes empresas y universidades: Thales Research and Technology, RCI, Institute d'electronique de Microelectrònique et de Nanotechnology (IEMN-CNRS), Institute d'Electronica Fondamentale (IEF), Consultora Navarra de Telecomunicaciones (CONATEL), Omicron Circuits s.l., Universitat Autònoma de Barcelona, y Universidad Pública de Navarra.
El presupuesto del proyecto es de 620.000 euros y su objetivo es el desarrollo, implementación y testeo de nuevos dispositivos basados en metamateriales, operando en las bandas de microondas y milimétricas, para telecomunicaciones. Varias de las propuestas de la presente tesis doctoral serán implementadas y testeadas en demostradores en este proyecto (en particular los filtros paso banda con rechazo de espúreos que utilizan la técnica “wiggly-line” y varias estructuras periódicas continuas optimizadas para el rechazo de armónicos y bandas frecuenciales no deseadas).
Este proyecto EUREKA se ha materializado en España en un Proyecto del Programa de Fomento de la Investigación Técnica (PROFIT): FIT-070000-2003-933, del Programa Nacional de Tecnologías de la Información y las Comunicaciones, Dirección general para el Desarrollo de la Sociedad de la Información, con idéntico título.
El coordinador del proyecto PROFIT es José A. Marcotegui, de la empresa Consultora Navarra de Telecomunicaciones, y los investigadores principales en la Universidad Pública de Navarra somos Mario Sorolla y el candidato José María Lopetegui.
El Partenariado español está formado por: Consultora Navarra de Telecomunicaciones (CONATEL), Omicron Circuits s.l., Universitat Autònoma de Barcelona, Universidad Pública de Navarra.
La subvención del proyecto es de 78.270 euros, con un anticipo reembolsable de 156.540 euros.
Como se ve, la participación del candidato en este proyecto junto con importantes empresas del sector de las telecomunicaciones muestra el interés de las empresas por los trabajos de esta tesis, y proporciona una excelente oportunidad y perspectiva para su desarrollo industrial.

3) Tesis escrita y defendida en inglés, ante un tribunal internacional

La tesis ha sido escrita y defendida en inglés, ante un tribunal internacional formado por científicos de reconocido prestigio en el campo de las microondas, entre los que se encontraban:

- Manfred Thumm (Catedrático del Instituto de Electrónica de Alta Frecuencia de la Universidad de Karlsruhe, y Director del Instituto de Impulsos de Potencia y Tecnología de Microondas, ambos en Karlsruhe, Alemania)
- Viktor Shevchenko (Investigador del Instituto de Radioingeniería y Electrónica de Moscú, Academia de Ciencias de Rusia)
- Tapani Närhi (Senior Microwave Engineer de la Agencia Espacial Europea)
- Carles Puente (Director de Tecnología de la empresa Fractus)

4) Selección del candidato como revisor de revistas científicas internacionales y libros:

El candidato ha sido seleccionado como revisor de artículos de las revistas científicas *IEEE Microwave and Wireless Components Letters* y *IEEE Transactions on Circuits and Systems I*

El candidato ha sido seleccionado como revisor de un capítulo del libro "Encyclopedia of RF and Microwave Engineering", de la editorial *John Wiley & Sons, Inc*.

Relación cronológica de todas las publicaciones nacionales o internacionales del autor relacionadas con la tesis

Publicaciones en revistas

(CLAVE: L = libro completo, CL = capítulo de libro, A = artículo, R = “review”, E = editor,
S = Documento Científico-Técnico restringido.)

Autores (p.o. de firma): F. Falcone, T. Lopetegi, J.D. Baena, R. Marqués, F. Martín and M. Sorolla
Título: “Effective negative-ε stop-band microstrip lines based on complementary split ring resonators”
Ref. revista / Libro: IEEE Microwave and Wireless Components Letters.
Clave: A Volumen: ACEPTADO, No. , Páginas, inicial: final: Fecha: 2004.
Editorial (si libro): Lugar de publicación:

Autores (p.o. de firma): F. Falcone, F. Martín, J. Bonache, R. Marqués, T. Lopetegi and M. Sorolla
Título: “Left handed coplanar waveguide band pass filters based on bi-layer split ring resonators”
Ref. revista / Libro: IEEE Microwave and Wireless Components Letters.
Clave: A Volumen: 14, No. 1, Páginas, inicial: 10 final: 12 Fecha: January 2004.
Editorial (si libro): Lugar de publicación:

Autores (p.o. de firma): F. Martín, J. Bonache, I. Gil, F. Falcone, T. Lopetegi, M.A.G,. Laso and M. Sorolla
Título: “Compact spurious free CPW band pass filters based on electromagnetic bandgap structures”
Ref. revista / Libro: Microwave and Optical Technology Letters
Clave: A Volumen: 40, No. 2, Páginas, inicial: 146 final: 148 Fecha: January 2004.
Editorial (si libro): Lugar de publicación:

Autores (p.o. de firma): F. Martín, F. Falcone, J. Bonache, M.A.G. Laso, T. Lopetegi, and M. Sorolla
Título: “New CPW low pass filter based on a slow wave structure”
Ref. revista / Libro: Microwave and Optical Technology Letters
Clave: A Volumen: 38, No. 3, Páginas, inicial: 190 final: 193 Fecha: August 2003.
Editorial (si libro): Lugar de publicación:

Autores (p.o. de firma): F. Martín, F. Falcone, J. Bonache, M.A.G. Laso, T. Lopetegi, and M. Sorolla
Título: “Dual electromagnetic bandgap CPW structures for filter applications”
Ref. revista / Libro: IEEE Microwave and Wireless Components Letters.
Clave: A Volumen: 13, No. 9, Páginas, inicial: 393 final: 395 Fecha: September 2003.
Editorial (si libro): Lugar de publicación:

Autores (p.o. de firma): F. Martín, J. L. Carreras, J. Bonache, T. Lopetegi, M.A.G. Laso, F. Falcone, and M. Sorolla
Título: “Frequency Tuning in Electromagnetic Bandgap Nonlinear Transmission Lines”
Ref. revista / Libro: Electronic Letters.
Clave: A Volumen: 39, No. 5, Páginas, inicial: 440 final: 442 Fecha: March 2003.
Editorial (si libro): Lugar de publicación:

Autores (p.o. de firma): Ferran Martín, Francisco Falcone, Jordi Bonache, Txema Lopetegi, Miguel A. G. Laso, J. L. Carreras, and Mario Sorolla
Título: “New electromagnetic bandgap nonlinear coplanar waveguides”
Ref. revista / Libro: Microwave and Optical Technology Letters.
Clave: A Volumen: 37, No. 6, Páginas, inicial: 397 final: 401 Fecha: Junio 2003.
Editorial (si libro): Lugar de publicación:

Autores (p.o. de firma): M. A. G. Laso, T. Lopetegi, M. J. Erro, D. Benito, M. J. Garde, M. A. Muriel, M. Sorolla, and M. Guglielmi
Título: “Real-time spectrum analysis in microstrip technology,”
Ref. revista / Libro: IEEE Transactions on Microwave Theory and Techniques.
Clave: A Volumen: 51, No. 3, Páginas, inicial: 705 final: 717 Fecha: Marzo 2003
Editorial (si libro): Lugar de publicación:

Autores (p.o. de firma): Ferran Martín, Francisco Falcone, Txema Lopetegi, Miguel A. G. Laso, and Mario Sorolla
Título: “Analyiss of the reflection properties in electromagnetic bandgap coplanar waveguides loaded with reactive elements – *full text*”
Ref. revista / Libro: Progress in Electromagnetic Research
Clave: A Volumen: PIER 42, No. , Páginas, inicial: 27 final: 48 Fecha: 2003.
Editorial (si libro): Lugar de publicación:

Autores (p.o. de firma): Ferran Martín, Francisco Falcone, Txema Lopetegi, Miguel A. G. Laso, and Mario Sorolla
Título: “Analyiss of the reflection properties in electromagnetic bandgap coplanar waveguides loaded with reactive elements - *abstract*”
Ref. revista / Libro: Journal of Electromagnetic Waves and Applications
Clave: A Volumen: 17, No. , Páginas, inicial: 1319 final: 1322 Fecha: 2003.
Editorial (si libro): Lugar de publicación:

Autores (p.o. de firma): Ferran Martín, Francisco Falcone, Jordi Bonache, Txema Lopetegi, Miguel A. G. Laso, and Mario Sorolla
Título: “Periodic-loaded sinusoidal patterned electromagnetic bandgap coplanar waveguides”
Ref. revista / Libro: Microwave and Optical Technology Letters.
Clave: A Volumen: 36, No. 3, Páginas, inicial: 181 final: 184 Fecha: February 2003
Editorial (si libro): Lugar de publicación:

Autores (p.o. de firma): M. J. Erro, M. A. G. Laso, T. Lopetegi, M. J. Garde, D. Benito, and M. Sorolla
Título: “A Comparison of the Performance of Different Tapers in Continuous Microstrip Electromagnetic Crystals”
Ref. revista / Libro: Microwave and Optical Technology Letters.
Clave: A Volumen: 36, No. 1, Páginas, inicial: 37 final: 40 Fecha: January 2003.
Editorial (si libro): Lugar de publicación:

Autores (p.o. de firma): Txema Lopetegi, Miguel A. G. Laso, Maria J. Erro, Mario Sorolla and Manfred Thumm
Título: “Analysis and Design of PBG Structures for Microstrip Lines by Using the Coupled Mode Theory”
Ref. revista / Libro: IEEE Microwave and Wireless Components Letters.
Clave: A Volumen: 12, No. 11, Páginas, inicial: 441 final: 443 Fecha: November 2002
Editorial (si libro): Lugar de publicación:

Autores (p.o. de firma): Ferran Martín, Francisco Falcone, Jordi Bonache, Txema Lopetegi, Miguel A.G. Laso, and Mario Sorolla
Título: “New periodic-loaded electromagnetic bandgap coplanar waveguide with complete spurious passband suppression”
Ref. revista / Libro: IEEE Microwave and Wireless Components Letters.
Clave: A Volumen: 12, No. 11, Páginas, inicial: 435 final: 437 Fecha: November 2002
Editorial (si libro): Lugar de publicación:

Autores (p.o. de firma): M. A. G. Laso, M. J. Erro, T. Lopetegi, M. J. Garde, D. Benito, and M. Sorolla
Título: “Cristales fotónicos. Estructuras periódicas para el control de la propagación electromagnética”
Ref. revista / Libro: Mundo Electrónico.
Clave: A Volumen:, No. 335, Páginas, inicial: 90 final: 95 Fecha: Octubre 2002.
Editorial (si libro): Lugar de publicación:

Autores (p.o. de firma): T. Akalin, M. A. G. Laso, E. Delos, T. Lopetegi, O. Vanbésien, M. Sorolla, and D. Lippens
Título: "High performance double-sided microstrip PBG filter"
Ref. revista / Libro: Microwave and Optical Technology Letters.
Clave: A Volumen: 35, No. 2, Páginas, inicial: 90 final: 93 Fecha: October 2002.
Editorial (si libro): Lugar de publicación:

Autores (p.o. de firma): F. Falcone, T. Lopetegi, M. A. G. Laso, and M. Sorolla
Título: "Novel Photonic Crystal Waveguide in Microwave Printed Circuit Technology"
Ref. revista / Libro: Microwave and Optical Technology Letters.
Clave: A Volumen: 34, No. 6 Páginas, inicial: 462 final: 466 Fecha: September 2002.
Editorial (si libro): Lugar de publicación:

Autores (p.o. de firma): F. Hirtenfelder, T. Lopetegi, M. Sorolla, and L. Sassi
Título: "Designing Components containing Photonic Bandgap Structures using Time Domain Field Solvers"
Ref. revista / Libro: Microwave Engineering Europe.
Clave: A Volumen: Páginas, inicial: 23 final: 29 Fecha: Marzo 2002
Editorial (si libro): Lugar de publicación:

Autores (p.o. de firma): T. Lopetegi, M. A. G. Laso, R. Gonzalo, M. J. Erro, F. Falcone, D. Benito, M. J. Garde, and M. Sorolla
Título: "Electromagnetic Crystals in Microstrip Technology"
Ref. revista / Libro Optical and Quantum Electronics.
Clave: A Volumen: 34, No. 1-3 Páginas, inicial: 279 final: 295 Fecha: Marzo 2002
Editorial (si libro): Lugar de publicación:

Autores (p.o. de firma): M. J. Erro, M. A. G. Laso, T. Lopetegi, D. Benito, M. J. Garde, and M. Sorolla
Título: "Analysis and Design of Electromagnetic Crystals in Microstrip Technology using a Fiber Grating Model"
Ref. revista / Libro: Optical and Quantum Electronics.
Clave: A Volumen: 34, No. 1-3, Páginas, inicial: 297 final: 310 Fecha: Marzo 2002
Editorial (si libro): Lugar de publicación:

Autores (p.o. de firma): M. A. G. Laso, T. Lopetegi, M. J. Erro, D. Benito, M. J. Garde, M. A. Muriel, and M. Sorolla
Título: "Chirped Delay Lines in Microstrip Technology"
Ref. revista / Libro: IEEE Microwave and Wireless Components Letters.
Clave: A Volumen: 11, No. 12, Páginas, inicial: 486 final: 488 Fecha: Diciembre 2001
Editorial (si libro): Lugar de publicación:

Autores (p.o. de firma): T. Akalin, M. A. Laso, T. L. Lopetegi, O. Vanbésien, M. Sorolla, and D. Lippens
Título: “PBG-type microstrip filters with one and two side patterns”
Ref. revista / Libro: Microwave and Optical Technology Letters.
Clave: A Volumen: 30, No. 1 Páginas, inicial: 69 final: 72 Fecha: July 2001.
Editorial (si libro): Lugar de publicación:

Autores (p.o. de firma): Txema Lopetegi, Miguel A. G. Laso, J. Hernández, M. Bacaicoa, David Benito, M. J. Garde, Mario Sorolla and Marco Guglielmi
Título: “New Microstrip “Wiggly-Line” Filters with Spurious Passband Suppression”
Ref. revista / Libro: IEEE Transactions on Microwave Theory and Techniques.
Clave: A Volumen: 49, No. 9 Páginas, inicial: 1593 final:1598 Fecha: Septiembre 2001
Editorial (si libro): Lugar de publicación:

Autores (p.o. de firma): Maria J. Erro, Miguel A.G. Laso, Txema Lopetegi, M. J. Garde and David Benito,
Título: “Electrically tunable dispersion compensation in a high bit rate TDM system using fiber Bragg grattings”
Ref. revista / Libro: Elecronics Letters.
Clave: A Volumen: 37, No. 13 Páginas, inicial: 847 final: 848 Fecha: Junio 2001
Editorial (si libro): Lugar de publicación:

Autores (p.o. de firma): Maria J. Erro, Miguel A.G. Laso, Txema Lopetegi, David Benito, M. J. Garde, and Mario Sorolla
Título: “Modeling and Testing of Uniform Fiber Bragg Gratings Using 1-D Photonic Bandgap Structures in Microstrip Technology”
Ref. revista / Libro: Journal of Fibre and Integrated Optics.
Clave: A Volumen: 19 Páginas, inicial: 311 final: 325 Fecha: Septiembre 2000
Editorial (si libro): Lugar de publicación:

Autores (p.o. de firma): Txema Lopetegi, Miguel A.G. Laso, Maite Irisarri, Maria J. Erro Francisco Falcone, and Mario Sorolla
Título: “Optimization of Compact Photonic Bandgap Microstrip Structure”,
Ref. revista / Libro: Microwave and Optical Technology Letters
Clave: A Volumen: 26 Páginas, inicial: 211 final: 216 Fecha: Agosto 2000
Editorial (si libro): Lugar de publicación:

Autores (p.o. de firma): Miguel A.G. Laso, Txema Lopetegi, Miguel Bacaicoa, Jorge Hernández, Ramón Gonzalo and Mario Sorolla
Título: “Arrangements of Via Holes in Microstrip Lines as Metallodielectric Periodic Structures”,
Ref. revista / Libro: Microwave and Optical Technology Letters
Clave: A Volumen: 26 Páginas, inicial: 372 final: 379 Fecha: Septiembre 2000

Autores (p.o. de firma): Miguel A.G. Laso, Txema Lopetegi, Maria J. Erro, David Benito, M.J. Garde, and Mario Sorolla
Título: “Multiple-Frequency-Tuned Photonic Bandgap Microstrip Structures”
Ref. revista / Libro: IEEE Microwave and Guided Wave Letters
Clave: A Volumen: 10, No. 6, Páginas, inicial: 220 final: 222 Fecha: Junio 2000
Editorial (si libro): Lugar de publicación:

Autores (p.o. de firma): Miguel A.G. Laso, Maria J. Erro, Txema Lopetegi, David Benito, M.J. Garde, and Mario Sorolla
Título: “Optimization of Tapered Bragg Reflectors in in Microstrip Technology”
Ref. revista / Libro: International Journal of Infrared and Millimeter Waves.
Clave: A Volumen: 21, No. 2, Páginas, inicial: 231 final: 245 Fecha: Febrero 2000
Editorial (si libro): Lugar de publicación:

Autores (p.o. de firma): Txema Lopetegi, Miguel A.G. Laso, Maria J. Erro, David Benito, M.J. Garde, Francisco Falcone and Mario Sorolla
Título: “Novel Photonic Bandgap Microstrip Structures Using Network Topology”
Ref. revista / Libro: Microwave and Optical Technology Letters.
Clave: A Volumen: 25, No. 1, Páginas, inicial: 33 final: 36 Fecha: Abril 2000
Editorial (si libro): Lugar de publicación:

Autores (p.o. de firma): Miguel A.G. Laso, Txema Lopetegi, Maria J. Erro, David Benito, M.J. Garde, and Mario Sorolla
Título: “Novel Wideband Photonic Bandgap Microstrip Structures”
Ref. revista / Libro: Microwave and Optical Technology Letters.
Clave: A Volumen: 24, No. 5, Páginas, inicial: 357 final: 360 Fecha: Marzo 2000
Editorial (si libro): Lugar de publicación:

Autores (p.o. de firma): Jaione Tirapu, Txema Lopetegi, Miguel A.G. Laso, Maria J. Erro, Francisco Falcone and Mario Sorolla
Título: “Study of the Delay Characteristics of 1-D Photonic Bandgap Microstrip Structures”
Ref. revista / Libro: Microwave and Optical Technology Letters
Clave: A Volumen: 23, No. 6, Páginas, inicial: 346 final: 349 Fecha: Diciembre 1999
Editorial (si libro): Lugar de publicación:

Autores (p.o. de firma): Francisco Falcone, Txema Lopetegi, Maite Irisarri, Miguel A.G. Laso, Maria J. Erro and Mario Sorolla
Título: “Compact Photonic Bandgap Microstrip Structure”,
Ref. revista / Libro: Microwave and Optical Technology Letters
Clave: A Volumen: 23, No. 4, Páginas, inicial: 233 final: 236 Fecha: Noviembre 1999
Editorial (si libro): Lugar de publicación:

Autores (p.o. de firma): Francisco Falcone, Txema Lopetegi, and Mario Sorolla
Título: “1-D and 2-D Phototonic Bandgap Microstrip Structure”
Ref. revista / Libro: Microwave and Optical Technology Letters.
Clave: A Volumen: 22, No. 6, Páginas, inicial: 411 final: 412 Fecha: Septiembre 1999
Editorial (si libro): Lugar de publicación:

Autores (p.o. de firma): Miguel A.G. Laso, Maria J. Erro, David Benito, M.J. Garde, Txema Lopetegi, Francisco Falcone, and Mario Sorolla
Título: “Analysis and Design of 1-D Photonic Bandgap Microstrip Structures Using a Fibre Grating Model”
Ref. revista / Libro: Microwave and Optical Technology Letters.
Clave: A Volumen: 22, No. 4, Páginas, inicial: 223 final: 226 Fecha: Agosto 1999
Editorial (si libro): Lugar de publicación:

Autores (p.o. de firma): Txema Lopetegi, Francisco Falcone, Beatríz Martínez, Ramón Gonzalo, and Mario Sorolla
Título: “Improved 2-D Phototonic Bandgap Structures in Microstrip Technology”
Ref. revista / Libro: Microwave and Optical Technology Letters
Clave: A Volumen: 22, No. 3 Páginas, inicial: 207 final: 211 Fecha: Agosto 1999
Editorial (si libro): Lugar de publicación:

Autores (p.o. de firma): Txema Lopetegi, Francisco Falcone, and Mario Sorolla
Título: “Bragg Reflectors and Resonators in Microstrip Technology based no Electromagnetic Crystal Structures”,
Ref. revista / Libro: International Journal on Infrared and Millimeter Waves,
Clave: A Volumen: 20, No. 6, Páginas, inicial: 1091 final: 1102 Fecha: Junio 1999
Editorial (si libro): Lugar de publicación:

Contribuciones a Congresos

Autores: Francisco Falcone, Ferran Martín, Jordi Bonache, Miguel A. G. Laso, Txema Lopetegi and Mario Sorolla
Título: "Implementation of Coplanar Waveguide Low Pass Filters by Using Electromagnetic Band-Gap Structures"
Tipo de Participación: Presentación Oral
Congreso: Progress In Electromagnetics Research Symposium (PIERS 2003)
Publicación: Libro de Abstracts
Lugar de Celebración: Hawaii Fecha: Octubre 2003

Autores: Miguel A. G. Laso, Txema Lopetegi, Francisco Falcone, Ferran Martin, David Benito, Mario Sorolla, and Tapani Närhi
Título: "Fourier Transform Using Microstrip Non-Uniform Periodic Structures: Survey of Potential Applications"
Tipo de Participación: Presentación Oral
Congreso: Progress In Electromagnetics Research Symposium (PIERS 2003)
Publicación: Libro de Abstracts
Lugar de Celebración: Hawaii Fecha: Octubre 2003

Autores: F. Falcone, F. Martín, J. Bonache, J. Martel, R. Marqués, T. Lopetegi, MAG Laso and M. Sorolla,
Título: "Implementation of Negative mu structures in Microstrip Technology",
Tipo de Participación: Presentación Oral
Congreso: 28th International Conference on Infrared and Millimeter Waves 2003
Publicación: Proceedings
Lugar de Celebración: Shiga, Japón Fecha: Octubre 2003

Autores: F. Falcone, F. Martín, J. Bonache, T. Lopetegi, M.A.G. Laso and M Sorolla,
Título: "Enhanced doubly-periodic Electromagnetic Bandgap Filter in Coplanar Waveguide Technology",
Tipo de Participación: Presentación Oral
Congreso: 28th International Conference on Infrared and Millimeter Waves 2003
Publicación: Proceedings
Lugar de Celebración: Shiga, Japón Fecha: Octubre 2003

Autores: F. Falcone, F. Martín, J. Bonache, T. Lopetegi, M.A.G. Laso and M.Sorolla,
Título: "Implementación de Filtros Paso Bajo EBG de doble periodicidad en Guía Coplanar."
Tipo de Participación: Presentación Oral
Congreso: XVIII Simposium Nacional de la Unión Científica Internacional de Radio 2003
Publicación: Proceedings
Lugar de Celebración: A Coruña Fecha: Sept. 2003

Autores: J. Illescas ,J.A. Marcotegui, F. Falcone, M.A.G. Laso, T. Lopetegi , F. Martín and M. Sorolla, Título: “Análisis de Estructuras EBG en guía coplanar mediante simulación basada en FDTD.”
Tipo de Participación: Presentación Oral
Congreso: XVIII Simposium Nacional de la Unión Científica Internacional de Radio 2003
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Lugar de Celebración: A Coruña Fecha: Sept. 2003

Autores: F. Falcone, F. Martin, J. Bonache, T. Lopetegi, M.A.G. Laso, M. Sorolla,
Título: “Analysis of Doubly Periodic Electromagnetic Bandgap Filters in Coplanar Waveguide Technology”,
Tipo de Participación: Presentación Oral
Congreso: 9th International Symposium on Microwave and Optical Technology, ISMOT 2003
Publicación: Proceedings
Lugar: Ostrava, República Checa Fecha: Ago. 2003

Autores: J.M Illescas, J.A. Marcotegui, F. Falcone , F. Martín , M.A.G. Laso, T. Lopetegi and M. Sorolla,
Título: “Simulation of EBG structures in coplanar waveguide with the aid of FDTD”,
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Lugar: Ostrava, República Checa Fecha: Ago. 2003

Autores: F. Falcone, F. Martín, J. Bonache, T. Lopetegi, M.A.G Laso and M. Sorolla,
Título: “Multiple Tuned continuous Electromagnetic Bandgap Structures in coplanar waveguide technology”,
Tipo de Participación: Presentación Oral
Congreso: 9th International Symposium on Microwave and Optical Technology, ISMOT 2003
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Título: “Implementation of Negative mu medium in Coplanar Waveguide technology”,
Tipo de Participación: Presentación Oral
Congreso: 9th International Symposium on Microwave and Optical Technology, ISMOT 2003
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Lugar: Ostrava, República Checa Fecha: Ago. 2003

Autores: Francisco Falcone, Txema Lopetegi, Miguel A. G. Laso, Ferran Martín, Jordi Bonache, Ricardo Marqués, and Mario Sorolla,
Título: "Electromagnetic band gaps in planar microwave technology",
Tipo de Participación: Presentación Oral, Invitada
Congreso: International Workshop on Optical properties of complex materials over different length scales, DIPC
Publicación: Proceedings
Lugar: San Sebastián Fecha: Julio. 2003

Autores: Francisco Falcone, Txema Lopetegi, Ferran Martín, Jordi Bonache, Ricardo Marqués, and Mario Sorolla
Título: "Novel metamaterial configurations in microwave and millimeter wave planar technology",
Tipo de Participación: Presentación Oral
Congreso: International Workshop on Optical properties of complex materials over different length scales, DIPC
Publicación: Proceedings
Lugar: San Sebastián Fecha: Julio. 2003

Autores: F. Martín, J. Bonache, I. Gil, F. Falcone, T. Lopetegi, M.A.G. Laso and M. Sorolla,
Título: "New capacitively coupled resonator band pass filters based on electromagnetic bandgaps"
Tipo de Participación: Presentación Oral, Invitada
Congreso: International Conference on Electromagnetics in Advanced Applications, ICEAA, 2003. Publicación: Proceedings
Lugar: Turín, Italia Fecha: Sept. 2003

Autores: A. Gonzalez, T. Lopetegi, M. A. G. Laso, F. Falcone, and M. Sorolla
Título: Intrinsic Harmonic Rejection in Active Antennas using PBG Structures
Tipo de participación: Poster
Congreso: Publicación: Asia Pacific Microwave Conference
Lugar de celebración: Kyoto, Japón Fecha: Noviembre 2002.

Autores: F. Martin, F. Falcone, J. Bonache, T. Lopetegi, M. A. G. Laso, M. Sorolla
Título: "A novel photonic bandgap periodic loaded coplanar waveguide structure,"
Tipo de participación: Poster
Congreso: Publicación: Microwave Technology and Techniques Workshop, pp. 131-137
Lugar de celebración: ESTEC (ESA), Noordwijk, The Netherlands. Fecha: October 2002.

Autores: L. Perez-Cuevas, M. Sorolla, T. Lopetegi, M. A. G. Laso, M. Guglielmi
Título: "Multispurious rejection in microstrip technology with "wiggly-line" band-pass filters,"
Tipo de participación: Poster
Congreso: Publicación: Microwave Technology and Techniques Workshop, pp. 95-102
Lugar de celebración: ESTEC (ESA), Noordwijk, The Netherlands. Fecha: October 2002.

Autores: F. Falcone, T. Lopetegi, M. A. G. Laso, F. Martin, J. Bonache, M. Sorolla,
Título: "Application of photonic bandgap structures for the implementation of bandpass filters in coplanar waveguide technology,"
Tipo de participación: Poster
Congreso: Publicación: Microwave Technology and Techniques Workshop, pp. 139-144
Lugar de celebración: ESTEC (ESA), Noordwijk, The Netherlands. Fecha: October 2002.

Autores: Txema Lopetegi, Miguel A. G. Laso, María J. Erro, José A. Leo, Mario Sorolla.
Título: "Application of the coupled mode theory to the analysis and design of PBG structures in microstrip technology"
Tipo de participación: Presentación Oral
Congreso: European Microwave Conference
Publicación: Proceedings
Lugar de celebración: Milano Fecha: Octubre 2002.

Autores: Miguel A. G. Laso, D. Benito, T. Lopetegi, M. J. Erro, M. J. Garde, Miguel A. Muriel, M. Sorolla, M. Guglielmi.
Título: "Microstrip Chirped Delay Lines based on Photonic Band-Gap Structures"
Tipo de participación: Presentación Oral
Congreso: European Microwave Conference
Publicación: Proceedings
Lugar de celebración: Milano Fecha: Octubre 2002.

Autores: Alejandro González Murua, Txema Lopetegi, Miguel A.G. Laso, and Mario Sorolla
Título: "Active Antenna with Intrinsic Harmonic Rejection by Using a Photonic Crystal"
Tipo de participación: Presentación oral.
Congreso: International Conference Infrared and Millimeter Waves
Publicación: Proceedings
Lugar de celebración: San Diego, California Fecha: Septiembre 2002.

Autores: Ferran Martín, Francisco Falcone, Jordi Bonache, Txema Lopetegi, Miguel A.G. Laso and Mario Sorolla
Título: "New PBG nonlinear distributed structures: application to the optimization of millimeter wave frequency multipliers"
Tipo de participación: Presentación oral.
Congreso: International Conference Infrared and Millimeter Waves
Publicación: Proceedings
Lugar de celebración: San Diego, California Fecha: Septiembre 2002.

Autores: Francisco Falcone, Ferran Martín , Jordi Bonache, Txema Lopetegi, Miguel A.G. Laso and Mario Sorolla,
Título: “PBG Resonator in Coplanar Waveguide Technology”
Tipo de participación: Presentación oral.
Congreso: International Conference Infrared and Millimeter Waves
Publicación: Proceedings
Lugar de celebración: San Diego, California Fecha: Septiembre 2002.

Autores: González Murua, Alejandro; Lopetegi Beregaña, Txema; Gómez Laso, Miguel Ángel.; Sorolla Ayza, Mario
Título: “Antena activa en sustrato cristal electromagnético”
Tipo de participación: Presentación Oral
Congreso: Publicación: Actas de URSI
Lugar de celebración: Alcalá de Henares Fecha: Septiembre 2002.

Autores: Gómez Laso, Miguel Ángel; Benito Pertusa, David; Ayala, Víctor; Sola, Carlos De; Lopetegi Beregaña, Txema; Erro Betrán, Mª José; Garde Alducin, María José; Sorolla Ayza, Mario
Título: “Filtros de fase cuadrática en tecnología Microstrip basados en estructuras den band-gap fotónico”
Tipo de participación: Presentación Oral
Congreso: Publicación: Actas de URSI
Lugar de celebración: Alcalá de Henares Fecha: Septiembre 2002.

Autores: Falcone, Francisco; Lopetegi Beregaña, Txema; Gómez Laso, Miguel Ángel; Sorolla Ayza, Mario; Martín, Ferrán; Bonache, Jordi
Título: “Aplicaciones de estructuras PBG en tecnología coplanar”
Tipo de participación: Presentación Oral
Congreso: Publicación: Actas de URSI
Lugar de celebración: Alcalá de Henares Fecha: Septiembre 2002.

Autores: F. Falcone, T. Lopetegi, M. A. G. Laso, and M. Sorolla
Título: “Characteristics of Novel 2d Electromagnetic Crystal Waveguides in Microstrip.”
Tipo de participación: Presentación Oral
Congreso: Mediterranean Microwave Symposium 2002
Publicación: Proceedings
Lugar de celebración: Cáceres Fecha: Junio 2002

Autores: M. A. G. Laso, T. Lopetegi, M. J. Erro, M. Castillo, D. Benito, M. J. Garde, M. A. Muriel, M. Sorolla, and M. Guglielmi
Título: “Real-time spectrum analysis in microstrip technology,”
Tipo de participación: Presentación Oral
Congreso: European Microwave Conference
Publicación: Proceedings
Lugar de celebración: Londres Fecha: Octubre 2001.

Autores F. Falcone, T. Lopetegi, M.A.G. Laso, R. Gonzalo, S. Arana, and M. Sorolla.
Título: "Novel 2D-Electromagnetic Crystal Waveguide in Microwave Printed Circuit Technology"
Tipo de participación: Presentación Oral
Congreso: European Microwave Conference
Publicación: Proceedings
Lugar de celebración: Londres Fecha: Octubre 2001.

Autores: F. Falcone, T. Lopetegi, M.A.G. Laso, and M. Sorolla,
Título: "Applications of Novel 2D-Electromagnetic Crystal Waveguide in Microwave Printed Circuit Technology"
Tipo de participación: Presentación oral.
Congreso: International Conference Infrared and Millimeter Waves
Publicación: Proceedings
Lugar de celebración: Toulouse, Francia Fecha: Septiembre 2001.

Autores: L. P. Cuevas, T. Lopetegi, M. A. G. Laso, D. Benito, M. J. Garde, M. Sorolla y M. Guglielmi
Título: "Filtros de líneas acopladas en tecnología microstrip con eliminación de bandas espurias"
Tipo de participación: Presentación oral.
Congreso: XVI Simposium Nacional U.R.S.I.,
Publicación: Libro de Actas
Lugar de celebración: Villaviciosa de Odón Fecha: Septiembre 2001.

Autores: T. Akalin, M. A. G. Laso, T. Lopetegi, O. Vanbésien, M. Sorolla, and D. Lippens
Título: "De la topologie micro-ruban vers les nouvelles structures periodiques pour le filtrage frequentiel"
Tipo de participación: Comunicación Oral
Congreso: IVemes Journees Nationales du Reseau Doctoral de Microelectronique
Publicación: Proceedings
Lugar de celebración: Strasbourg, France Fecha: Abril 2001.

Autores: M.A.G. Laso, T. Lopetegi, M. Bacaicoa, J. Hernández, M.J. Garde, and M. Sorolla
Título: "Arrangements of Via-Holes in Microstrip Lines as Metallodielectric Periodic Structures"
Tipo de participación: Poster
Congreso: Asia-Pacific Microwave Conference
Publicación: Proceedings
Lugar de celebración: Sydney Fecha: Diciembre 2000.

Autores: M.A.G. Laso, T. Lopetegi, R. Gonzalo, M. J. Erro, D. Benito, M. J. Garde, P. De Maagt, and M. Sorolla.
Título: “Applications of Electromagnetic Crystals in microstrip Technology”
Tipo de participación: Invitación a Sesión Especial
Congreso: European Microwave Conference
Publicación: Proceedings
Lugar de celebración: París Fecha: Octubre 2000.

Autores: Miguel A. G. Laso, Txema Lopetegi, Maria J. Erro, David Benito, Maria J. Garde, y Mario Sorolla.
Título: “Estructuras continuas de *Bandgap* Fotónico en tecnología *Microstrip* con sintonía múltiple”
Tipo de participación: Comunicación oral
Congreso: URSI’2000
Publicación: Actas
Lugar de celebración: Zaragoza Fecha: Septiembre 2000.

Autores M. Anaya, J. A. Marcotegui, T. Lopetegi, M.A.G. Laso, and M. Sorolla
Título: “Analysis of New Periodic Structures in Microstrip by FDTD”
Tipo de participación: Comunicación oral
Congreso: European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS)
Publicación: Proceedings
Lugar de celebración: Barcelona Fecha: Septiembre 2000.

Autores T. Lopetegi, M. A. G. Laso, M. J. Erro, R. Gonzalo, J. Tirapu, A. Marcotegui, D. Benito, M. J. Garde, M. Sorolla.
Título: “Photonic Crystals in Microstrip Technology”
Tipo de participación: Poster
Congreso: NATO Advanced Studies Institute in Photonic Crystals
Publicación: Proceedings
Lugar de celebración: Creta Fecha: Junio 2000.

Autores: M. Irisarri, T. Lopetegi, M.A.G. Laso, F. Falcone, and M. Sorolla.
Título: “Optimization of compact photonic bandgap microstrip structures”
Tipo de participación: Poster
Congreso: Millenium Conference no Antennas and Propagation
Publicación: Proceedings
Lugar de celebración: Davos, Suiza Fecha: Abril 2000.

Autores: T. Lopetegi, M. A. G. Laso, M. J. Erro, R. Gonzalo, J. Tirapu, A. Marcotegui, D. Benito, M.J. Garde, and M. Sorolla
Título: “Electromagnetic Crystals in Microstrip Technology”
Tipo de participación: Poster
Congreso: International Workshop on Photonic and Electromagnetic Crystal Structures (PECS)
Publicación: Technical Digest
Lugar de celebración: Sendai, Japón Fecha: Marzo 2000.

Autores: T. Lopetegi, M.A.G. Laso, M.J. Erro, D. Benito, M.J. Garde, F. Falcone, and M. Sorolla.
Título: “Microstrip Continous Gratings”
Tipo de participación: Comunicación oral
Congreso: International Symposium on Recent Advances in Microwave Technology ISRAMT,
Publicación: Proceedings
Lugar de celebración: Torremolinos Fecha: Diciembre 1999.

Autores: T. Lopetegi, M.A.G. Laso, M.J. Erro, D. Benito, M.J. Garde, F. Falcone, and M. Sorolla.
Título: “New Results in Microstrip Grating Technology”
Tipo de participación: Conferencia invitada
Congreso: International Symposium on Recent Advances in Microwave Technology ISRAMT,
Publicación: Proceedings
Lugar de celebración: Torremolinos Fecha: Diciembre 1999.

Autores: T. Lopetegi, M. A. G. Laso, M. J. Erro, F. Falcone and M. Sorolla
Título: “Bandpass Filter in Microstrip Technology using Photonic Bandgap Reflectors”
Tipo de participación: Presentación oral.
Congreso: European Microwave Conference
Publicación: Proceedings
Lugar de celebración: Munich Fecha: Octubre 1999.

Autores: M. J. Erro, T. Lopetegi, M. A. G. Laso, D. Benito, M. J. Garde, F. Falcone, and M. Sorolla
Título: “Novel Wideband Photonic Bandgap Microstrip Structures”
Tipo de participación: Presentación oral.
Congreso: European Microwave Conference
Publicación: Proceedings
Lugar de celebración: Munich Fecha: Octubre 1999.

Autores: M.J. Asarta, A. Escudero, M.A.G. Laso, M.J. Erro, T. Lopetegi, D. Benito, M.J. Garde, y M. Sorolla,
Título: “Analisis y Diseño de Estructuras de *Bandgap Fotónico* en Microstrip Usando un Modelo Equivalente de Red de Difracción Óptica”,
Tipo de participación: Presentación oral.
Congreso: Simposium Nacional URSI,
Publicación: Actas
Lugar de celebración: Santiago de Compostela Fecha: Septiembre 1999.

Autores: M.A.G. Laso, T. Lopetegi, M.J. Erro, D. Benito, M.J. Garde, M. Sorolla
Título: “Aplicación de Técnicas para el Aumento de Ancho de Banda a Estructuras de *Bandgap Fotónico* en Tecnología Microstrip”
Tipo de participación: Presentación oral.
Congreso: Simposium Nacional URSI,
Publicación: Actas
Lugar de celebración: Santiago de Compostela Fecha: Septiembre 1999.

Autores: M. Ezcurra, R. Artieda, M. J. Erro, M.A.G. Laso, T. Lopetegi, D. Benito, M. J. Garde y M. Sorolla
Título: “Estudio Comparativo de las Prestaciones Obtenidas por Distintas Ventanas Aplicadas a Estructuras de *Bandgap Fotónico* en Tecnología Microstrip”
Tipo de participación: Presentación oral.
Congreso: Simposium Nacional URSI,
Publicación: Actas
Lugar de celebración: Santiago de Compostela Fecha: Septiembre 1999.

Autores: Jaione Tirapu, Txema Lopetegi, Francisco Falcone and Mario Sorolla,
Título: “Dispersion cancellation using 1-D Photonic Bandgap Microstrip Structures in Transmission”
Tipo de participación: Presentación oral.
Congreso: International Conference no Infrared and Millimeter Waves
Publicación: Proceedings
Lugar de celebración: Monterey USA Fecha: September 1999.

Autores: M.A.G. Laso, M.J. Erro, T. Lopetegi, D. Benito, M.J. Garde, F. Falcone, and M. Sorolla,
Título: “Optimization of Tapered Photonic Bandgap Structures in Microstrip”
Tipo de participación: Presentación oral.
Congreso: International Conference Infrared and Millimeter Waves
Publicación: Proceedings
Lugar de celebración: Monterey USA Fecha: September 1999.

Autores: M. J. Erro, T. Lopetegi, M. A. G. Laso, D. Benito, M. J. Garde, F. Falcone, and M. Sorolla
Título: “An Extended Model Based on the Coupled-Mode Theory in Fibre Gratings for the Analysis and Design of 1-D Photonic Bandgap Devices in Microstrip Technology”
Tipo de participación: Presentación oral.
Congreso: International Conference SPIE
Publicación: Proceedings of SPIE
Lugar de celebración: Denver, CO, USA Fecha: Julio 1999

Autores: Lopetegui, T., Falcone, F., Martínez, B., Ederra, I., Gonzalo, R. y Sorolla, M.
Título: “Photonic Bandgap Resonator Structures in Microstrip”.
Tipo de participación: Presentación oral.
Congreso: Asia- Pacific Microwave Conference.
Publicación: Proceedings of the 1998 Asia- Pacific Microwave Conference.
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Autores: Falcone, F., Lopetegui, T., Martínez, B., Gonzalo, R. y Sorolla, M.
Título: “New 1-D and 2-D Photonic Bandgap Structures in Microstrip”.
Tipo de participación: Presentación oral.
Congreso: XXVIII Moscow International Conference on Antenna Theory and Technology
Publicación: Proceedings *XXVIII Moscow International Conference on Antenna Theory and Technology*
Lugar de celebración: Moscú, Rusia Fecha: Septiembre 1998

Autores: Falcone, F., Lopetegui, T., Martínez, B., Gonzalo, R. y Sorolla, M.
Título: “Diseño de Estructuras de Bandgap Fotónico 2-D Optimizadas en Tecnología Microstrip”.
Tipo de participación: Presentación oral.
Congreso: XIII Simposium Nacional U.R.S.I.
Publicación: Libro de Actas del XIII Simposium Nacional U.R.S.I.
Lugar de celebración: Pamplona Fecha: Septiembre 1998

Autores: Lopetegui, T., Falcone, F., Martínez, B., Gonzalo, R. y Sorolla, M.
Título: *“Improved 2-D photonic bandgap microstrip structures”*.
Tipo de participación: Presentación oral.
Congreso: 23rd International Conference on Infrarred and Millimeter Waves
Publicación: Proceedings of the 23rd International Conference on Infrarred and Millimeter Waves
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