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# Low Cost Self-Diplexed Antenna in Inverted Microstrip Gap Waveguide Technology

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***Abstract* –Low cost low-loss self-diplexed slot antenna is described. The antenna is built using a novel microstrip waveguide technology, formed between two parallel metal plates without the requirements of electrical contact between these plates. The diplexer is realized by using a texture of screws as Artificial Magnetic Conductor (AMC) and two parallel coupled lines passband filters (BPFs), and the radiating slot is placed in the smooth top plate. The diplexer layout has been optimized in order to ensure compactness. The diplexer shows excellent performance in terms of high isolation and low insertion loss.**

***Index Terms* —Coupled lines passband filter, perfect electric conductor (PEC), perfect magnetic conductor (PMC), gap waveguide (GWG), waveguide slot antenna.**

## I. Introduction

A diplexer is a device that allows two separate systems to share a single antenna. A diplexer consists of two separate filters that match the bandpass and bandwidth requirements of each connected system. In satellite communications, for example, diplexers transmit-receive part of the transponder payload and are used to properly isolate signals uplink and downlink, which share the same antenna. In this sense, this device must have low insertion loss to allow the reception of the signal rising while maximizing the transmitted signal power down. At the same time, it must be selective enough to avoid the interference from the downlink and uplink signals. Therefore, in such applications the most important design parameter is the insertion loss of the filters, and the isolation level.

The GAP waveguide technology (GWG) is a new microwave circuit technology that has major advantages for use in the frequency band from 30 GHz to Terahertz frequencies [1]. The GAP waveguides have smaller losses than commonly used microstrip lines and coplanar waveguide, based on metal strips on a dielectric substrate. They have also lower losses than so-called substrate integrated waveguides (SIW). Moreover the groove GAP waveguide version can have similar losses as commonly-used entire-metal rectangular waveguides, but are on the other hand more cost-effective in production because they can be made without conducting joints between metal parts. The GAP waveguides can also be used for eliminating cavity modes appearing when packaging passive and active circuits based on microstrip and coplanar waveguides [2]. The superior performances of the GAP waveguide technology both as a transmission line for making advanced microwave circuits and as a packaging technology, have already been verified and described in several scientific journal articles, letters and conference papers [3-5].

This paper presents a low cost self-diplexed slot antenna operating at 10 and 12 GHz, manufactured later in printed circuited board thanks to the microstrip GWG technology with low cost, weight and size.

## II. Designing The Filters

Two microstrip fifth order coupled-line bandpass filters have been designed for ~10% bandwidth. The center frequency of the passbands were chosen to be $f_o$ = 10 GHz and 12 GHz respectively in order to work at a frequency where we can use coaxial connectors and available vector network analyzer.

The two prototypes have been designed to produce a Chebyshev response in a fifth order filter with 0.03 dB ripple. The material used as substrate for both filters is Rogers RO4003C™ with relative permittivity $\varepsilon_r$ = 3.55, loss tangent tanδ = 0.0027, and thickness $h$ = 0.813 mm. Nevertheless the wave propagates in air, and this material is just the support for the printed parts.

## III. Designing the diplexor

The power divider is based on diplexer presented on [6]. In that proposed narrow band diplexer design, two different quarter wavelength lines ($l_1$ and $l_2$) at the center frequencies ($f_2$ and $f1$) of two BPFs are used to separate the BPFs. Since the quarter wavelength impedance transformer (at $f_o$) transforms a low impedance level (≈0) to a high impedance region (≈∞) at the frequency of $f_o$, it can be used for narrow band microstrip circuit design to change the impedance level.

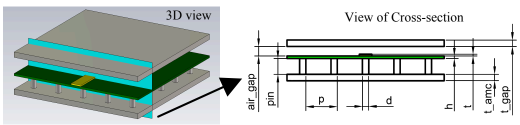
## IV. Designing The Stop Band

As mentioned in [5], the main performance of the gap waveguide is determined by its ability to create parallel-plate stopband for wave propagation in undesired directions. This ability is determined by the quasi-periodic pin structure and the height of the air gap. How to design such type of structures can be found in [7].

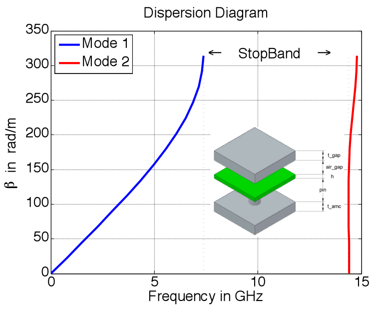
We use a textured surface made of screws, modeled by cylindrical pins. This surface is designed to have the stopband covering 8–14 GHz. The dispersion diagrams for the parallel-plate geometry with metal pins that are used is shown in Fig. 1. The screw dimensions are also shown in the figure.

As shown in the figure, a large stop-band is created by the pin surface after 8 GHz where all the parallel-plate modes are in cutoff. Once the dimensions of the periodic pin structure are obtained, the diplexer circuit can be incorporated on the periodic pin structure.

Fig. 2 shows s parameters for the microstrip-gap diplexer. Isolation parameter S21, is below -30dB on desired band.




(a)




(b)

Fig. 1 (a) Detailed dimensions of the periodic metal pin and microstrip waveguide geometry used. (b) Dispersion diagram of the unit cell of the periodic pins used in the diplexor design, *d = 2 mm, pin= 5 mm, p = 10 mm,* $air_{gap}$ *= 1 mm, h = 0.813 mm, t = 0.035 µm, t_amc = t_gap = 2 mm*.

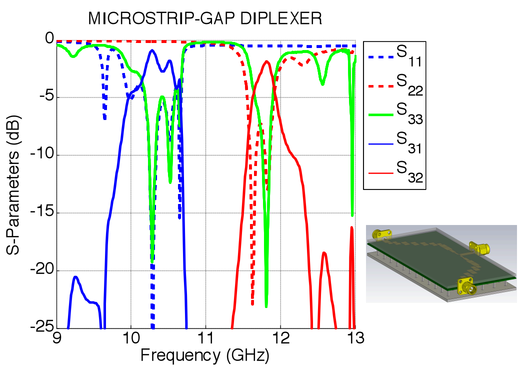



Fig. 2. Simulated s-parameters for the microstrip-gap diplexer (experimental results will be presented at the conference).

## V. Antenna Design

The design of the slot antenna in the paper is based on T-shaped microstrip-fed printed slot antenna [8]. It has been optimized entirely by numerical simulations using a cut-and-try approach based on intelligent guessing from previous experience. Fig. 3 shows the self-diplexed antenna layout and simulated $S_{11}$, $S_{22}$. Isolation parameter $S_{21}$, is below -30dB on desired band.

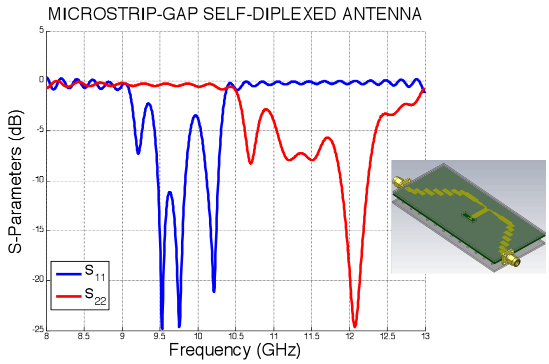



Fig. 3. Simulated s-parameters for the low cost self-diplexed antenna (experimental results will be presented at the conference).

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