A New Type of Slow-wave PBG Microstrip Structures

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I. Introduction

Microstrip planar waveguides are popular and widely used passive components. They play an important place in microwave hybrid integration (MIC). Microstrip, as a planar technology, is, also, compatible with microelectronic technology and has a future in microwave monolithic integration (MMIC).

Passive components at microwave frequencies, especially at lower bands, are still large and occupy a lot of space. One of the main goals for all passive components, including that in the microstrip technology, is miniaturization.

Solution for the miniaturization of the microstrip structures can be a periodical variation of the characteristic impedance, Z_C, along the microstrip signal line. It forms a photonic bandgap (PBG) structure. PBG structures, as it is known, exhibit slow-wave characteristics in the pass-band near bandgap [1]. The structure can also exhibit an additional slow-wave effect owing to decrease of the propagation velocity $(L^{`}C^{`})^{-1/2}$. It is based on increasing both distributed inductance $L^{`}$ and capacitance $C^{`}$ along the microstrip line. At the same time, the average ratio of the inductance and capacitance should remain relatively constant (usually around 50 Ω) for matching input and output lines (usually 50 Ω lines).

Previous solution for the microstrip periodic strictures was etching in the ground plane [2]. The etched ground plane must be far enough from any metal plate, which causes packaging problems. The packaging problems are with space, cooling, and mechanical strength. Also, there is a technological problem with etching of the both sides of the substrate. Next solution is to modify only the microstrip line without etching in the ground plane [3].

In ref. [4-6] author have introduced a new type of 1D slow-wave PBG microstrip structures. It has no etching in the ground plane and has a simple modification of the microstrip line. The basic cell is applied to five different structures. They all exhibit significant slow-wave effect.

II. Basic Cell of the Proposed Slow-Wave PBG Structures

One cell of the proposed type of structures is presented in Fig.1. Inductance corresponds to the narrow lines. Capacitance corresponds mainly to the wide areas (width *W* and length *d*) on the both sides of the central line.

Changing the width of the narrow line, *t*, and the width *W* one can change the slow-wave factor. Also, appropriate combination of the width *W* and the width t can be used for matching to impedances of the input and the output lines. The length *d* has influence on the position of the bandgap.

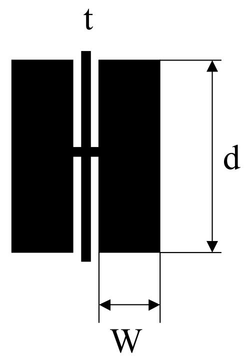

Fig.1- One cell of the proposed type of microstrip structures

III. Low-Pass Filter

The first realized structure is a low-pass filter [4]. Its lay-out is shown in Fig.2.

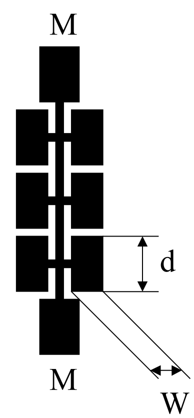

Fig.2- Lay-out of the realized slow-wave low-pass filter (*W*=1.3mm; *d*=3mm)

An example of the proposed low-pass filter was realized on the dielectric substrate, ε_r =2.17 and thickness *h*=0.508 mm. The width of the narrow lines and slots are 0.2 mm each. Middle narrow line is connected to the 50 Ω lines as shown in Fig.2. The 50 Ω lines are 1.6mm wide and 2mm long each to support connectors. In the realized sample wide areas are *d*=3mm long and *W*=1.3mm wide each. The realized structure contains 3 cells in a serial connection with the total length of only 9.8 mm (without 50 Ω lines which support connectors).

Phase responses of the proposed structure (including the ordinary 50 Ω lines for the connectors; Fig. 2) and the

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ordinary 50 Ω line of the same length are presented in Fig.3. Proposed structure has steep characteristics, especially near the bandgap, which gives high slow-wave factor. The slow-wave enhancement over an ordinary 50 Ω line of the same length is from 1.8 (below 1 GHz) to 5.5 (around 9 GHz). Simulated S-parameters for the proposed low-pass filter are shown in Fig.4. Measured results are shown in Figs.5a and 5b. Bandgap is –60dB deep and S_{11}-parameters are below –10dB in the whole band-pass.

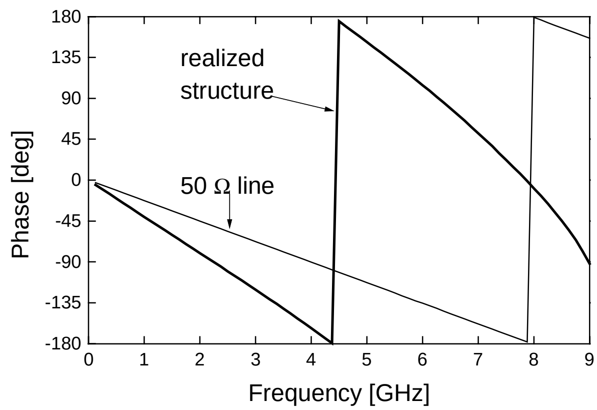

Fig.3-Phase responses of the realized structure with three cells (including the ordinary 50 Ω lines for the connectors; Fig.2) and the ordinary 50 Ω line of the same length

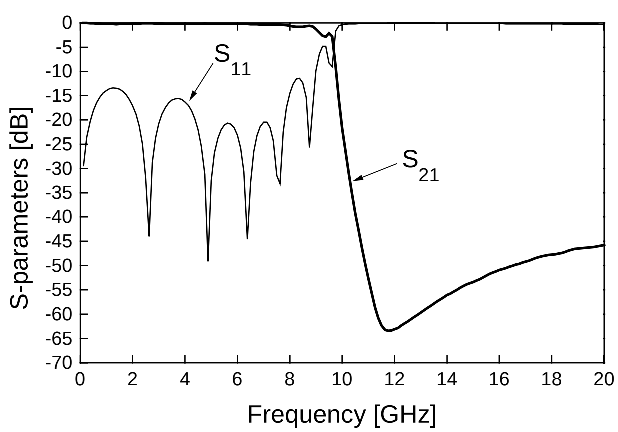

Fig. 4- Simulated *S*- parameters for the realized lowpass filter with three cells

IV. BAND-PASS FILTER

The second realized structure is a band-pass filter with a half-wavelength resonator with 6 cells [5,6]. An example of the proposed band-pass filter was realized on the dielectric substrate: ε_r=2.1, thickness h=0.508 mm and $tg\delta$=4·10^{-4}. The lay-out of the proposed band-pass filter is presented in Fig.6.

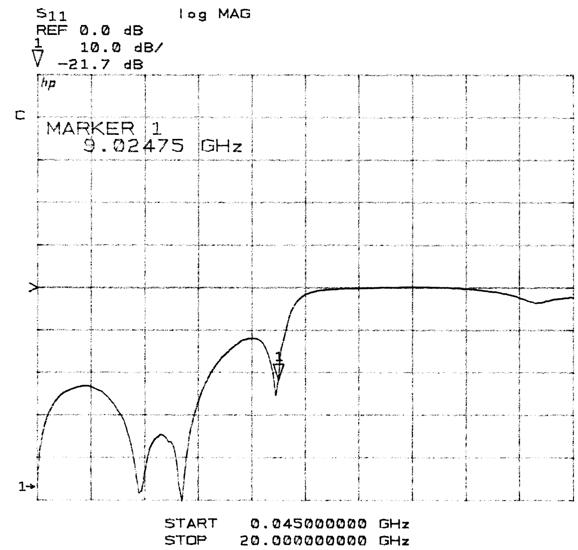

Fig.5a- Measured S_{11} parameters for the realized low-pass filter with three cells

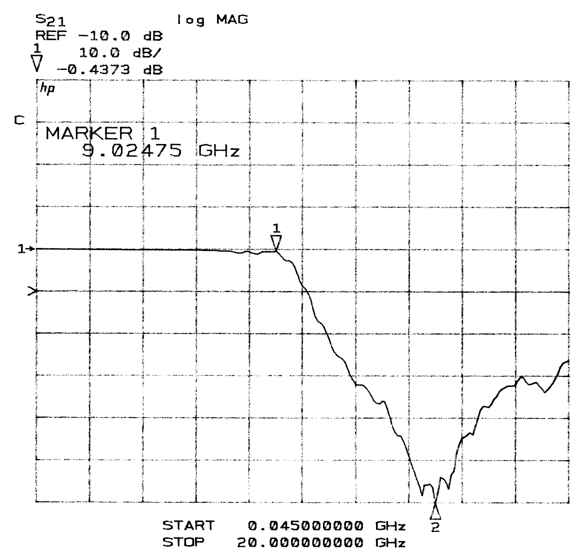

Fig.5b- Measured S_{21} parameters for the realized low-pass filter with three cells

Inductance corresponds to the narrow lines. Capacitance corresponds mainly to the wide areas (width *W* and length *d* or *k* respectively in Fig.6) on the both sides of the central line. Coupling is between resonator and a wide line (M in Fig.6) on the both sides. Both M lines are linearly tapered to the width of an ordinary 50Ω line. Additional coupling is over a tuning narrow line (L in Fig.6) on the both sides. Each tuning line extends to the half of the resonator. For the proposed structure all narrow lines are 0.2 mm wide. For the wide areas: *W*=1.3 mm, *d*=1.4 mm and *k*=0.8 mm. Each "M" line is 2 mm long (for a connector) and each narrow end corresponds to the width 1.6 mm of an ordinary 50Ω line. Coupling slots are 0.1 mm wide and all other slots are 0.2 mm wide

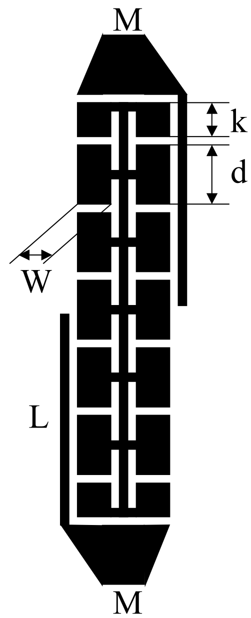

Fig.6- Lay-out of the realized slow-wave band-pass filter (*W*=1.3mm; *d*=1.4mm; *k*=0.8mm)

It has reduction of the central frequency (slow-wave effect) more than 50% comparing to the conventional band-pass filter of the same length and width (5 GHz against 10.4 GHz). Additional coupling is over tuning narrow lines (L in Fig.6) that can be used to regulate the filter performances. Tuning lines support lower losses but wider band-pass. Simulated and measured S-parameters of the proposed band-pass filter are shown in Fig.7 and Fig.8 respectively.

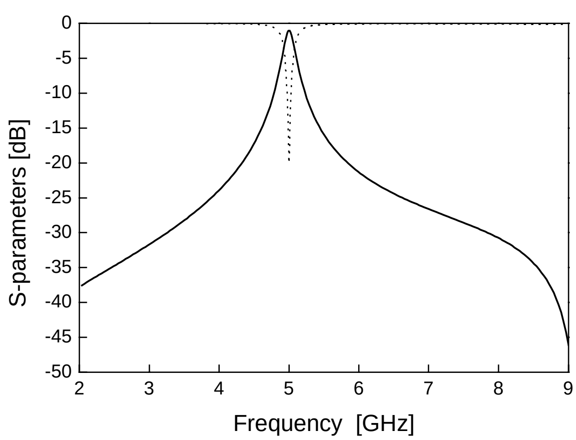

Fig.7- Simulated *S*-parameters for the proposed structure in Fig.6 (S_{21}-solid line; S_{11}-dot line)

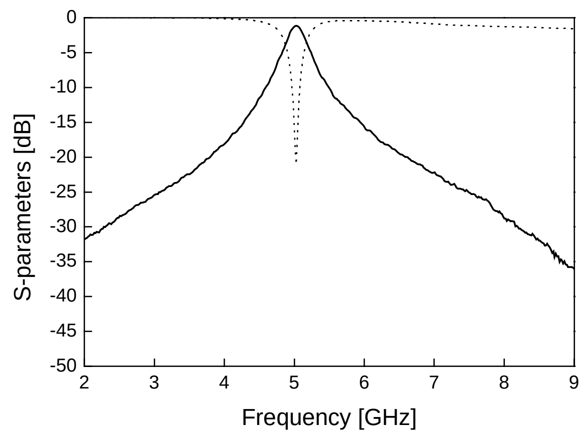

Fig.8- Measured *S* parameters for the proposed structure in Fig.6 (S_{21}-solid line; S_{11}-dot line)

The second band-pass filter has additional coupling lines around the whole resonator. Its lay-out is presented in Fig.9. They increase coupling between the resonator and the input and the output lines.

The band-pass filter presented in Fig.9 gives lower losses (less than 1 dB) and wider band-pass. Simulated S-parameters are presented in Fig.10.

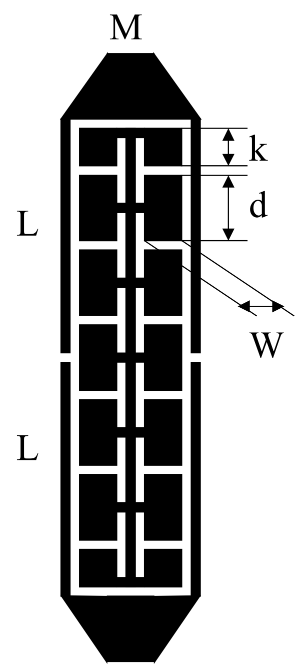

Fig.9- Additional coupling lines around the whole resonator

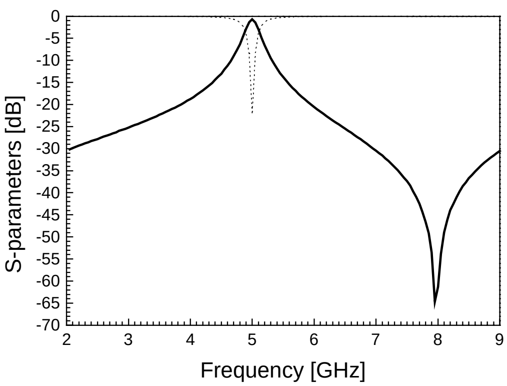

Fig.10- Simulated S-parameters for the structure presented in Fig.7
(S_{21}-solid line; S_{11}-dot line)

V. Filter with a Ring Resonator

The next structure is a ring resonator. Its lay-out is shown in Fig.11. Reduction of the central frequency is over 50% comparing to the conventional ring resonator of the same outer radius (1.24 GHz against 2.5 GHz). Dielectric substrate: ε_r=2.1, thickness h=0.508 mm and $tg\delta$=$4\cdot10^{-4}$. The inner radius is 12 mm. Six planes corresponding to the capacitance, *W* in Fig.11, are 2.6 mm wide each. All narrow lines are 0.2 mm wide. Coupling gaps (close to the coupling line L) are 0.1 mm wide each. Simulated and measured results are presented in Fig.12 and Fig.13 respectively.

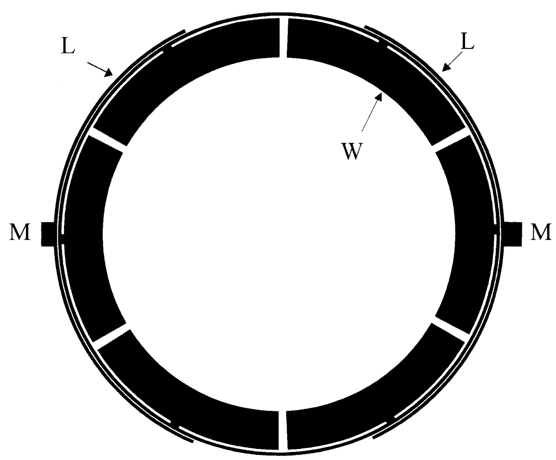

Fig.11- Lay-out of the proposed ring resonator

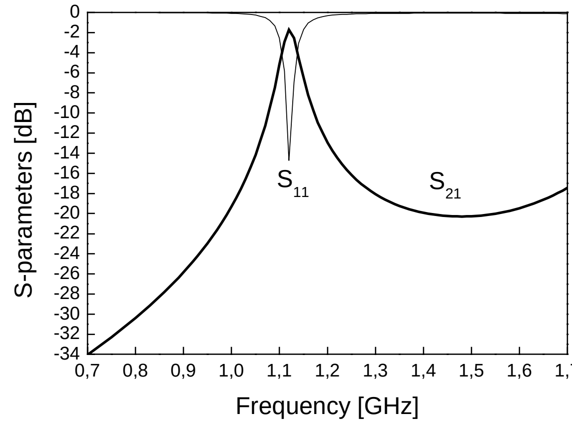

Fig.12- Simulated *S*-parameters for the structure presented in Fig.11

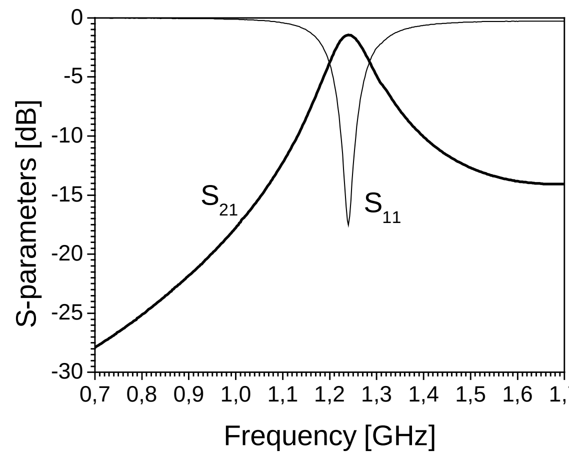

Fig.13- Measured *S*-parameters for the structure presented in Fig.11

VI. Matching Line in a T-junction

A successful application of only one cell is described in the last realized structure. It is a matching line in a T-junction between three 50 Ω lines. Its lay-out is shown in Fig. 14. Dielectric substrate: ε_r=2.1, thickness h=0.508 mm and $tg\delta$=$4\cdot10^{-4}$. M-lines, Fig.14, are 1.6 mm wide 50 Ω lines. Simulated and measured S-parameters are shown in Fig.15 and Fig.16 respectively.

Reduction of the length of the λ/4 matching line is 60% comparing to the conventional λ/4 line.

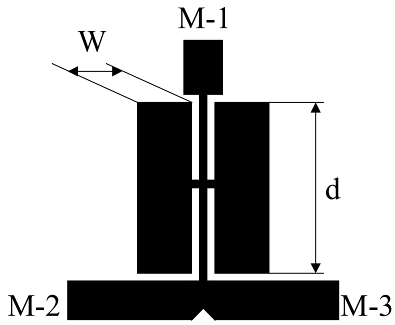

Fig.14- Lay-out of the proposed matching line in a *d*=9.7 mm; narrow lines are 0.2 mm wide each)

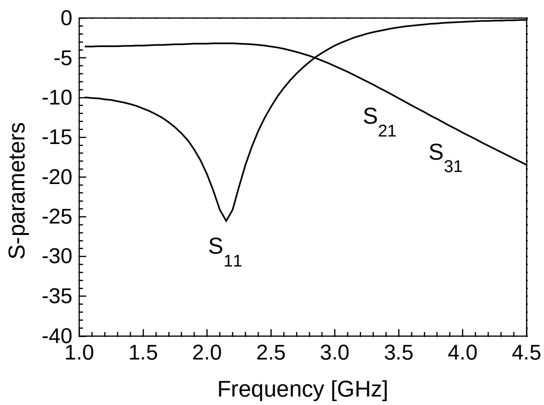

Fig.15- Simulated *S*-parameters for the structure presented in Fig.14

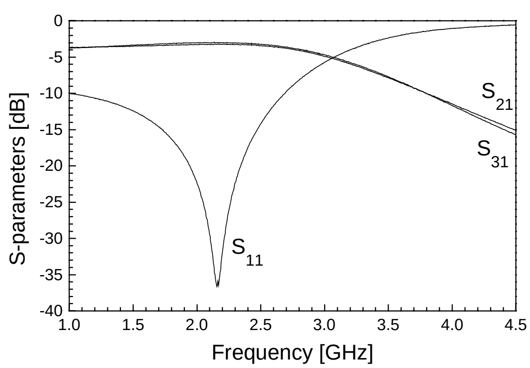

Fig.16- Measured *S*-parameters for the structure presented in Fig.14

VII. Conclusion

A new type of 1D slow-wave PBG microstrip structures is introduced. They have no etching in the ground plane and have a simple modification of the microstrip line.

The basic cell is applied to five different structures. They include four different but important applications. They all exhibit significant slow-wave effect and the reduction of the lengths is 50% or more.

Also, S-parameters are very good and agreement between simulation and measurement is reasonable.

VIII. Acknowlegement

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IX. References

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