

FOLDED STUBS FOR COMPACT SUSPENDED STRIPLINE CIRCUITS

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ABSTRACT

Coupled line sections using both sides of a suspended stripline substrate can be regarded as stubs folded closely parallel to the stripline giving a number of advantages like compact setup, a simple, one-channel stripline mount, no waveguide modes, and additional degrees of freedom for circuit design. By an appropriate design, open and short-circuited series as well as shunt stubs covering a wide range of stub impedances can be realized. As examples for their application, a bandpass, a highpass, and a bandstop filter are presented.

BASIC CIRCUIT ELEMENTS

Although suspended stripline (SSL) requires a more complicated setup compared to microstrip or coplanar line due to the shielding mount, it shows advantages concerning Q-factor and losses or the absence of radiation. Furthermore, both sides of the substrate are available for circuit patterns enabling broadside coupling or the combination of suspended substrate line with microstrip or coplanar line [1].

For example, a section of broadside coupled stripline as shown in Fig. 1a can be regarded, too, as an open series stub with its typical highpass characteristic (Fig. 1b).

Although a more exact theoretical description is given by coupled transmission line theory or by full-wave methods, the imagination of a stub may be nearer to an engineers intuition. Following this idea and including via connections and side connections to the stripline mount, short circuited and open series as well as shunt "stubs" can be realized as shown in Figs. 1 and 2. To a great extent - at least up to "stub" lengths of $\lambda/2$ - these structures behave very similar to real stub circuits. Modifying the line widths, the range of characteristic impedances can be adjusted between a few Ohms up to more than 150 Ω . The advantages of these structures are

- Additional, partly new circuit elements
- Compact setup
- Simple and small stripline mount (only a single channel)
- No waveguide modes in the stripline channel.

Designing components with these elements, the following procedure seems to be a good choice:

- The conception of the circuit can be done using the easy understood stub model.
- A more exact first design step is made using (coupled) transmission line theory. The coupled line parameters can be calculated, for example, using spectral domain methods, e.g. [2].
- The final optimization and control of the circuit requires full-wave methods, especially if higher frequencies are involved.

FULL-WAVE COMPUTATION

The fundamental method used for the full-wave analysis of the filter, presented in this paper is the well-known Mode-Matching-Technique (MMT) [e.g. 3].

In order to apply this method, the complex structure has to be divided in waveguide sections, having the same outer shielding dimensions and constant geometrical and electrical parameters. Each of these sections themselves will be splitted again in subsections of three fundamental types: the homogeneous filled waveguide, the dielectric layered waveguide, and the dielectric layered waveguide containing of at least one metal strip of finite thickness inside the shielding box, according to Fig. 3.

In a first step, the eigenvalues for these waveguide subsections are determined. The eigenvalues of the rectangular waveguide can be found analytically, the eigenvalues for the dielectric layered waveguide are formulated in a matrix equation; in the special case of a two layer problem the eigenvalues are the solutions of a transcendent equation [4]. In case of the hybrid mode waveguides the MMT is used, i.e. the eigenfunctions are a superposition of an infinite sum of subeigenfunctions itself [5].

In a second step, the continuity conditions for the tangential electromagnetic field components at the interfaces between the waveguide subsections have to be fulfilled simultaneously using the MMT, too.

These calculations lead to the desired scattering matrix formulation for the physical two-ports.

The procedure described above was implemented on a Hewlett-Packard workstation of the HP9000/700 family using the programming language C++. The benefits of this language, i.e. object oriented programming, was used to provide a flexible program for a wide range of different structures and for ease of extension to compute multiports, for example.

I. Bandpass filter

The bandpass filter (Fig. 4) is formed by two quarter-wave short-circuited shunt stubs connected by a high impedance quarter-wave transmission line. The original design of the low-impedance stubs was done employing coupled transmission line theory. Due to the quarter-wave lengths of all lines, an automatic suppression of an additional passband at twice the center frequency is achieved.

The experimental results are compared with a full-wave computation of the complete filter. A very good agreement can be found, even concerning the spurious line of the insertion loss at 6.8 GHz.

II. Highpass filter

The highpass filter (Fig. 5) consists of a low impedance open series "stub" combined with a high impedance short-circuited shunt "stub". Both "stubs" are a quarter wavelength at about 10 GHz. To increase the impedance of the shunt stub, part of the metallization of the strip on the opposite side was removed. This is of minor influence on that strip, as the currents are mainly concentrated at the strip edges. While already the broadside coupled line section (series stub) provides a wideband highpass performance (Fig. 5, thin lines), the shunt stub results in a considerable improvement in the behaviour around the corner frequency (fat lines). In this way, a 2-18 GHz highpass filter could be realized. Its length in a 5 mm by 5 mm channel amounts to only 12 mm, showing that very compact circuits can be realized in this way.

III. Bandstop filter

Finally, a bandstop filter combining a low-impedance short-circuited series "stub" and a high impedance open shunt "stub" was designed and tested (Fig. 6). This circuit is - to some extent - complementary to the highpass filter as described before. Once again, part of the bottom strip is removed to increase the impedance of the shunt stub. A wide passband with acceptable losses was achieved. The theoretical full-wave results differ slightly from the experimental results. Some deviation of the stopband is due to a slight difference of the shunt stub length in the realized structure. Furthermore, a mismatch of the transition from coaxial line to SSL caused a ripple in the return loss curve.

CONCLUSION

Very compact suspended stripline circuits have been presented using the concept of folded stubs. This method can be extended, too, to coplanar circuits if an additional dielectric layer and a second strip metallization are used. Such miniaturized circuits may even be used on microwave and mm-wave MMICs /6/.

- /1/ Menzel, W.: Broadband Filter Circuits Using an Extended Suspended Substrate Transmission Line Configuration. 22nd European Microwave Conference (1992), Helsinki, pp. 459-463.
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- /3/ Bögelsack, F., Wolff, I.: Full-Wave Analysis of Multiport Microstrip Discontinuities Using a Superposition Principle and Mode-Matching Technique. Int. Journ. of Numerical Modelling. Electronic Networks, Devices and Fields, J. Wiley & Son, Vol. 3 (1990), 259-268.
- /4/ R. E. Collin: Field Theory of Guided Waves, McGraw-Hill, New York, 1960.
- /5/ G. Kowalski, R. Pregla: 'Dispersion characteristics of shielded microstrips with finite thickness', Arch. Elektr. Übertr. (AEÜ), 25, 193-196 (1971).
- /6/ Menzel, W. et al.: Compact Multilayer Filter Structures for Coplanar MMIC's. IEEE Microw. and Guided Wave Letters, Vol. 2, Dec. 1992, 497-498.

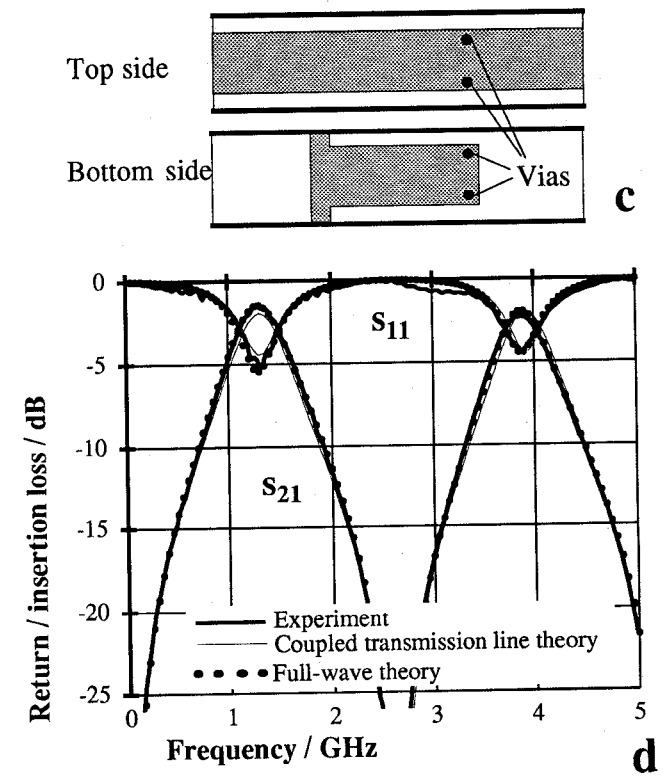
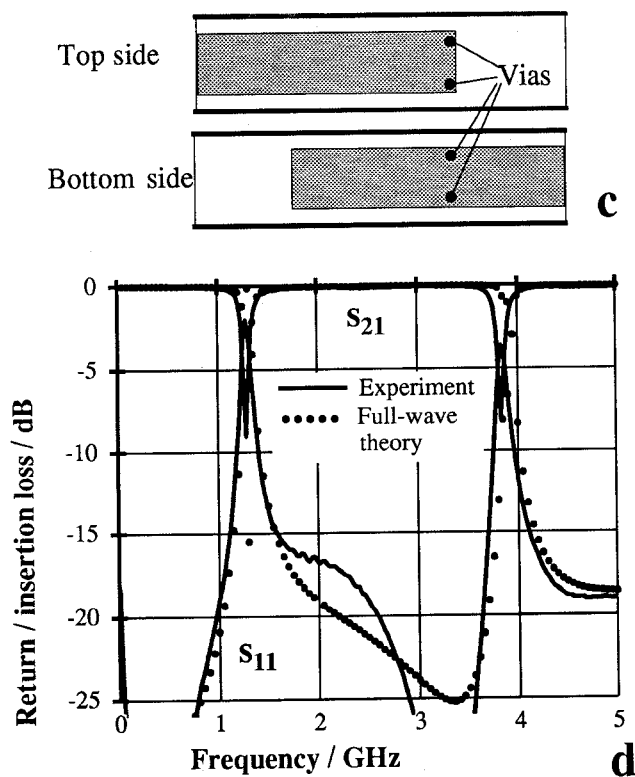
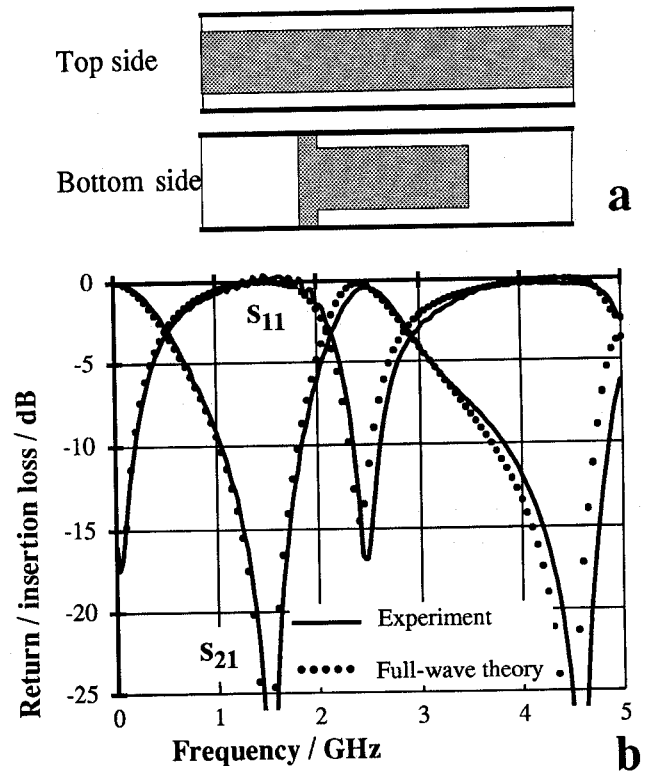
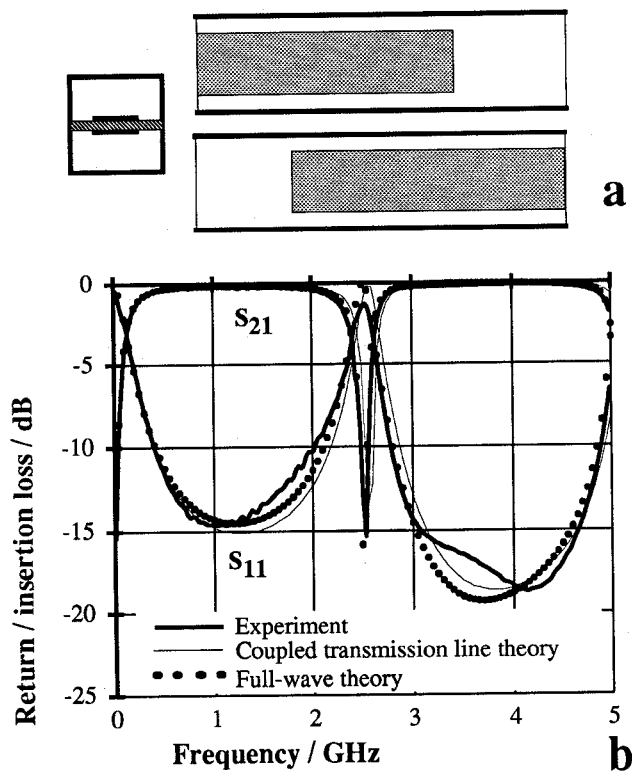


Fig. 1: Configuration and transmission characteristics of open and short-circuted series "stubs". (Channel: $5 \times 5 \text{ mm}^2$, stub lengths: 40 mm, line width: 4 mm, substrate thickness: 0.254 mm, $\epsilon_r=2.22$).

Fig. 2: Configuration and transmission characteristics of open and short-circuted shunt "stubs". (Channel: $5 \times 5 \text{ mm}^2$, stub lengths: 40 mm, line width: 4 mm, substrate thickness: 0.254 mm, $\epsilon_r=2.22$).

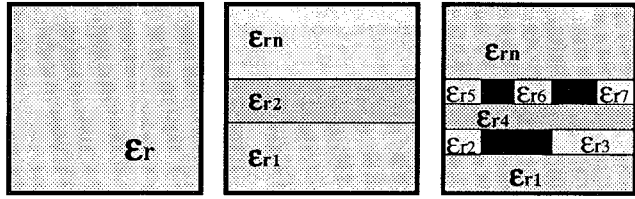


Fig. 3: Cross sections of the three fundamental waveguide types.

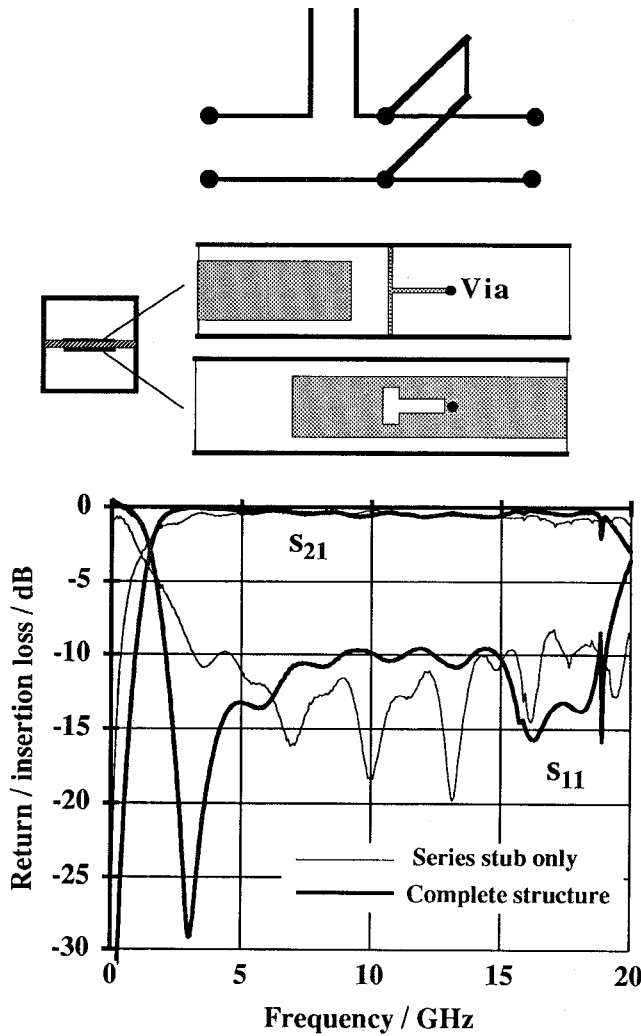


Fig. 5: Configuration and transmission characteristics of the lowpass filter. (Overlapping of series stub 4.1 mm; parallel stub: line width 0.1 mm, stub lengths 3.2 mm).

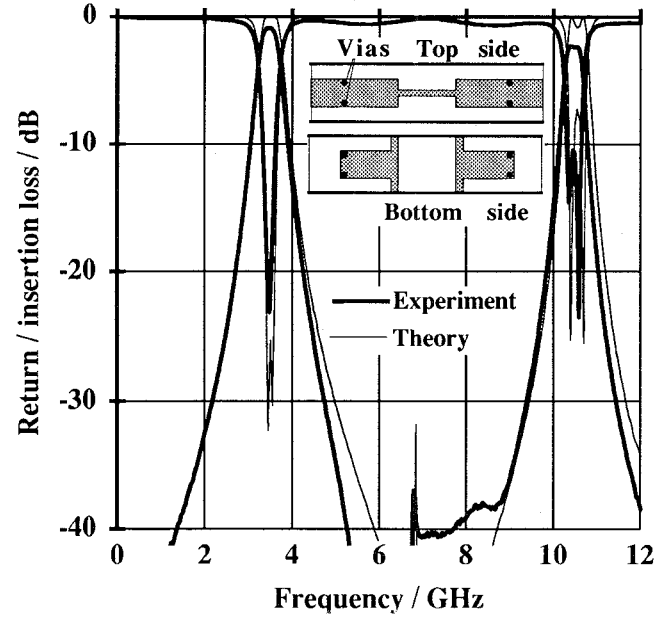


Fig. 4: Configuration and transmission characteristics of the bandpass filter. (Line widths 4 and 0.45 mm, stub lengths 13.5 mm, center line length 19 mm).

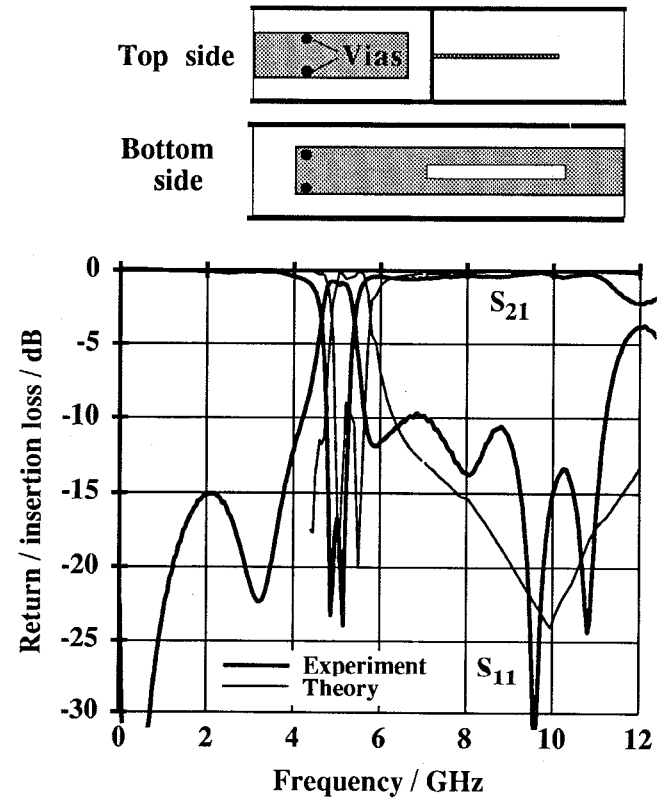


Fig. 6: Configuration and transmission characteristics of the bandstop filter. (Series stub: length 10.1 mm; parallel stub: line width 0.1 mm, length 3.5 mm).