Ultra-Wideband (UWB) Filter With WLAN Notch

Wolfgang Menzel, Peter Feil

Microwave Techniques, University of Ulm, PO Box, D-89069 Ulm, Germany,
E-mail: wolfgang.menzel@ieee.org

***Abstract* — Strong narrowband signals like WLAN links may severely disturb UWB communication or sensor systems. In some cases, filtering out the respective frequency bands may therefore be of interest. This contribution proposes an additional notch filter within the passband of a broadband filter normally used to tailor the UWB spectrum. To this extent, a resonant slot is incorporated into one of the elements of a suspended stripline filter. Simulated and experimental results of a filter of this kind are presented, demonstrating the feasibility of this approach.**

***Index Terms* — Planar transmission lines, planar microwave filters, stripline filters, ultra-wideband filters.**

I. INTRODUCTION

With increasing interest in UWB application, quite a number of efforts have been done to investigate different types of components. To confine the spectrum to the assigned frequency band, filters of different kinds have been proposed, e.g. [1-4]. One general problem of UWB systems is a possible interference with relatively strong narrowband signals within the allocated UWB spectrum like those from WLAN applications. Therefore, a number of antenna designs have been presented including a notch filter to reject critical frequencies, e.g. at 5.8 GHz. Typically, folded slot resonators are included into the radiator design, for example [5,6].

In [4], two types of suspended stripline (SSL) filters were demonstrated including resonators which, to some extent, resemble the form of UWB monopole radiators. Therefore, the idea came up to include a notch filter into wideband UWB bandpass filters as well.

II. SSL UWB BANDPASS FILTER WITH NOTCH

The general structure of a third order SSL highpass filter as used in one of the designs in [4] is depicted in Fig. 1. The SSL substrate of 0.254 mm thickness is suspended in a metal channel of 6 mm width and 4.25 mm height. Input and output lines are broadside coupled to a wide section of transmission line. This central line segment is connected to ground by a thin strip acting as inductor. An inset increases its value. Thus, this structure represents a highpass filter with two series capacitances and a shunt inductor. To provide the rejection of a small frequency band, a slot resonator is included into the patch. To ensure a resonance at a sufficiently low frequency, a Duroid RT 6010 substrate with a dielectric constant of 10.2 and a folded slot are selected. The overall structure is optimized such that, on the one hand, the lower cut-off frequency is at about 3 GHz, and the slot resonance is at 5.8 GHz. Fig. 2 shows simulated [7] insertion and return loss of this filter structure. Its lower cut-off frequency matches with the UWB requirements; its passband is sufficiently wide as well. At 5.8 GHz, a deep notch results from the folded slot. By changing the length of the slot – either by moving the outer ends or by shifting the central part as indicated in Fig. 1 (bottom), the notch frequency can be adjusted (Fig. 3).

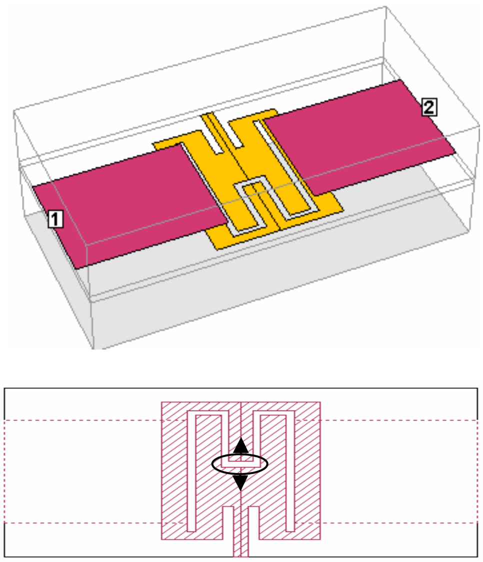

Fig. 1: General structure and layout of the SSL filter with notch.

To improve the upper stopband performance of the filter, a lowpass filter was connected in series to the highpass filter as indicated in the layout of Fig. 4. Inductances are realized by thin strips, capacitances are characterized by a backside metallization under the respective elements. Due to the high dielectric constant and the cut-off frequency of 10 GHz, such capacitive elements are quite small. Simulated and experimental return and insertion loss are plotted in Fig. 5, a photograph is shown in Fig. 6. The general performance is met very well; the notch frequency and the upper corner frequency of the filter, however, are shifted to lower frequencies by about 0.4 GHz and 0.75 GHz, respectively.

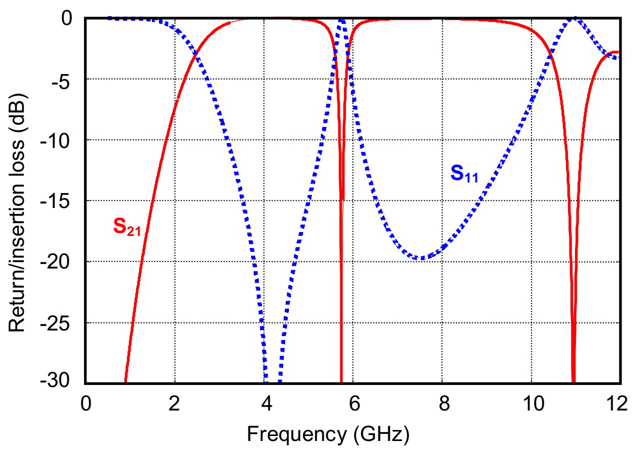

Fig. 2: Simulated return and insertion loss of the SSL highpass filter with notch.

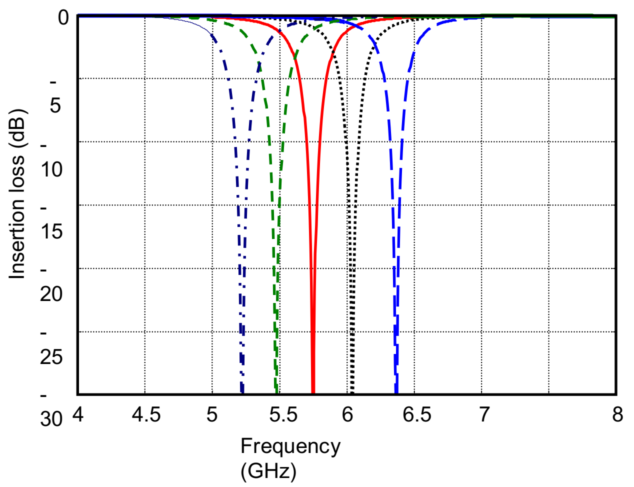

Fig. 3: Simulated insertion loss of the SSL highpass filter with different lengths of the slot.

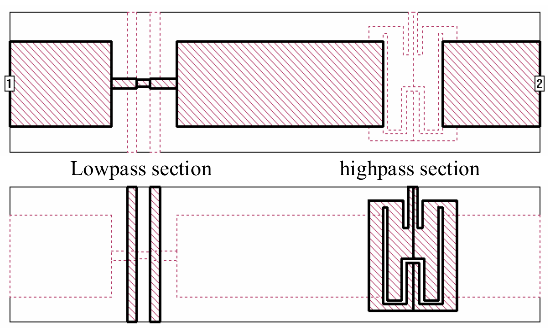

Fig. 4: Top and bottom layout of the complete SSL bandpass filter with notch.

Detailed investigations have been made to find out the reason for the shift in notch frequency, including simulation accuracy, fabrication tolerances, finite metallization thickness, or influence of skin effect. None of these could explain the amount and the direction of frequency shift sufficiently; the only remaining effect was some roughness of the edge metallization of the slot; a simulation [7] of a slot line with a small ripple gave similar results. As a first test, the length of the slot was reduced by soldering bond ribbons over its ends. As can be seen in Fig. 7, the notch frequency could be adjusted to the desire value. At the same time, the upper corner frequency of the filter was shifted to a higher frequency as well. Further investigations revealed that another portion of the shift in upper corner frequency is caused by the influence of the clamping groves (to hold the substrate) on the behavior of the ground strips of the lowpass filter.

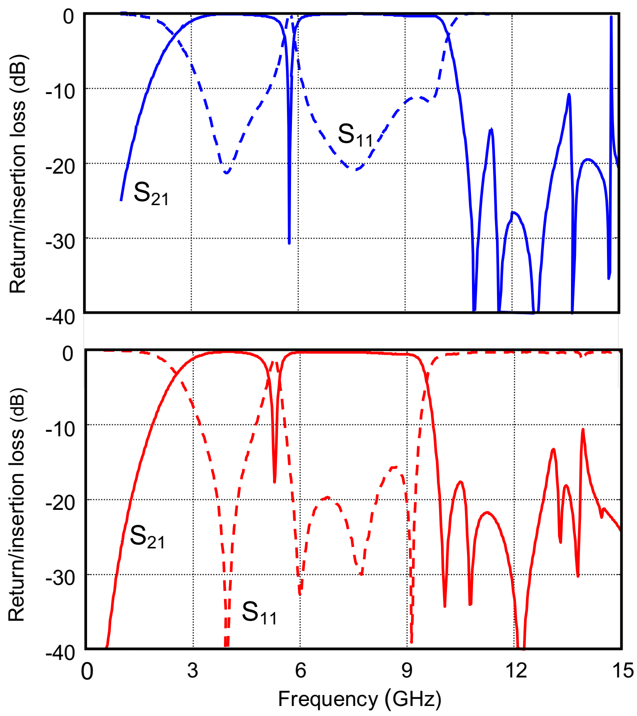

Fig. 5: Simulated (top) and experimental (bottom) return and insertion loss of the SSL bandpass filter with notch.

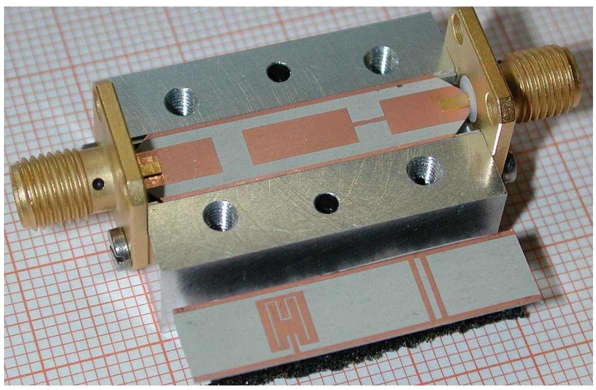

Fig. 6: Photograph of the realized filter.

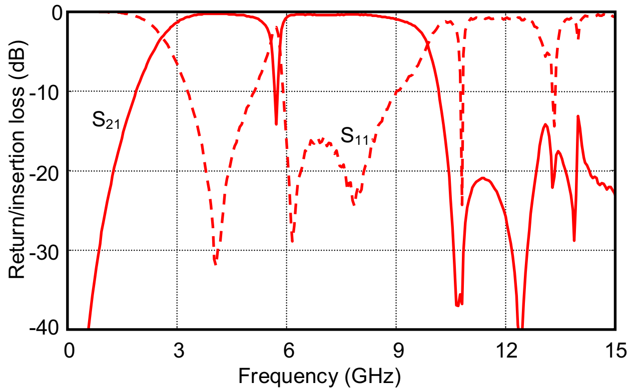

Fig. 7: Experimental return and insertion loss of the SSL bandpass filter with reduced length of the slot.

Consequently, a redesign was done taking into account the effects of the clamping groves and reducing the length of the slot for the notch. The results of this redesigned filter are shown in Fig. 8. Except for some slight problem at the upper edge of the passband, the filter now provides a satisfactory performance and a good agreement between simulation and experiment.

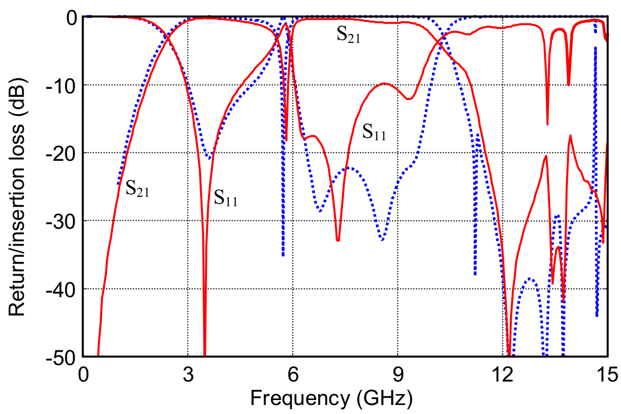

Fig. 8: Simulated (dotted lines) and experimental (solid lines) return and insertion loss of the redesigned SSL bandpass filter.

III. Influence of the Filter on UWB Signals

A general problem with quickly changing filter responses due to the notch, however, is an increase in group delay variation and consequently, some signal distortion. This is not only true for the filter as presented here, but also for the transfer functions of antennas including such a notch [5,6]. The simulated group delay of this filter is shown in Fig. 9. Except for the region around the notch, group delay variation is below 0.3 ns; the notch, however, results in an increase to 1.2 ns. A separate investigation has therefore been made on the influence of this filter on the shape of a Gaussian UWB monocycle. To this extent, spectrum and time domain response of a suitable Gaussian monocycle were calculated. Following this, the *experimental* performance of a standard UWB filter as reported in [4] and that of the filter from Fig. 7 were used to calculate both the resulting spectral and time domain responses. Fig. 10 a displays the input spectrum of the Gaussian monocycle before and after filtering with the "normal" UWB filter, Fig. 10 b the time domain responses of incident and filtered Gaussian monocycle. The UWB filter used for this investigation has a group delay variation of less than 0.15 ns. Figs. 11 a and b show the respective curves for the UWB notch filter as described above. As the filter response as shown in Fig. 7 is used, the upper band edge frequency is slightly lower than that of the "normal" UWB filter, and due to the steeper upper slope, group delay variation is slightly higher than with the normal UWB filter described in [4]. With both filters, the effect of differentiation on the pulse form can be recognized. For the filter with the notch, an additional ringing can be seen which, for increasing time, has exactly the resonance frequency of the notch. The slot resonator is excited by the monocycle, and its energy leaks away after the end of the pulse.

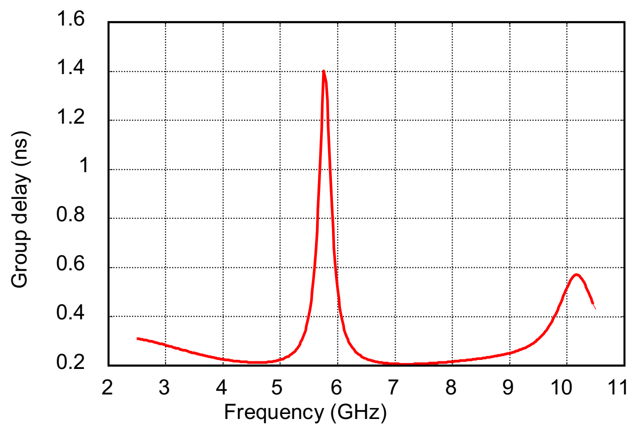

Fig. 9: Simulated group delay of the UWB notch filter.

IV. Conclusion

In this paper, a UWB bandpass filter is presented which, within its wide passband, includes a narrow bandstop (notch). This notch can be easily tuned to reject interfering signals, e.g. by WLAN connections. The general performance of the filter is very good. The notch leads to some additional ringing of a transmitted Gaussian monocycle, but the distortion is not very large compared to a UWB filter without notch.

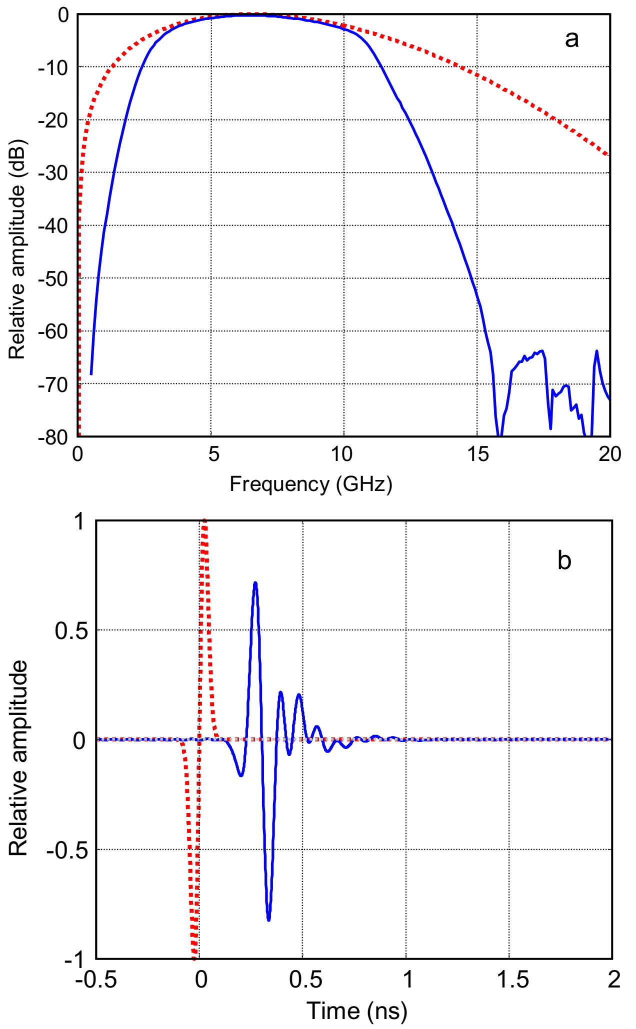

Fig. 10: Spectrum (a) and time domain shape (b) of a Gaussian monocycle before and after passing a UWB filter according to [4]. Dotted lines: Characteristics before, solid lines after passing the filter.

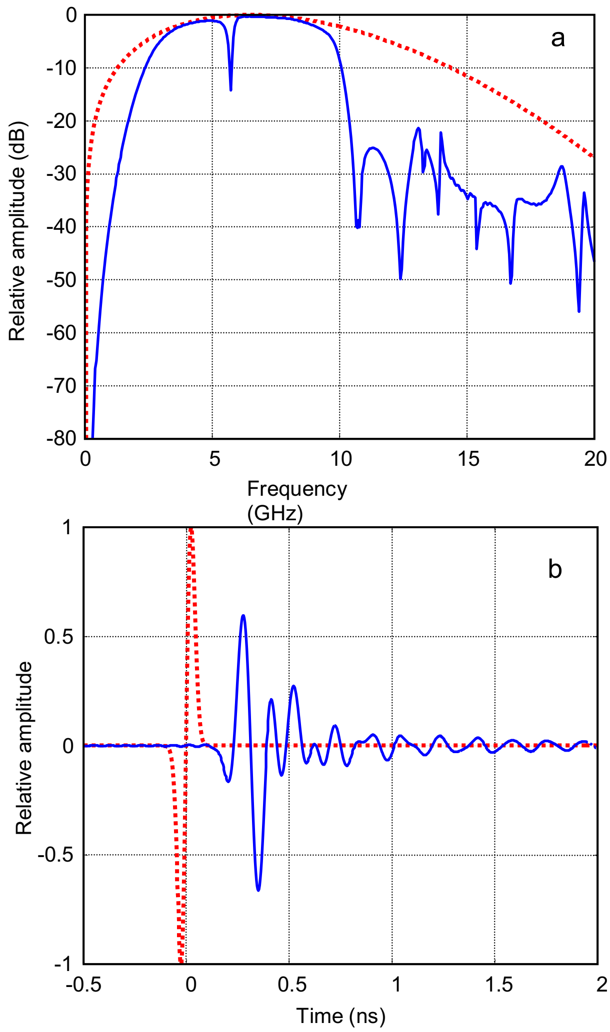

Fig. 11: Spectrum (a) and time domain shape (b) of a Gaussian monocycle before and after passing a UWB filter with a 5.8 GHz notch. Dotted lines: Characteristics before, solid lines after passing the filter.

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