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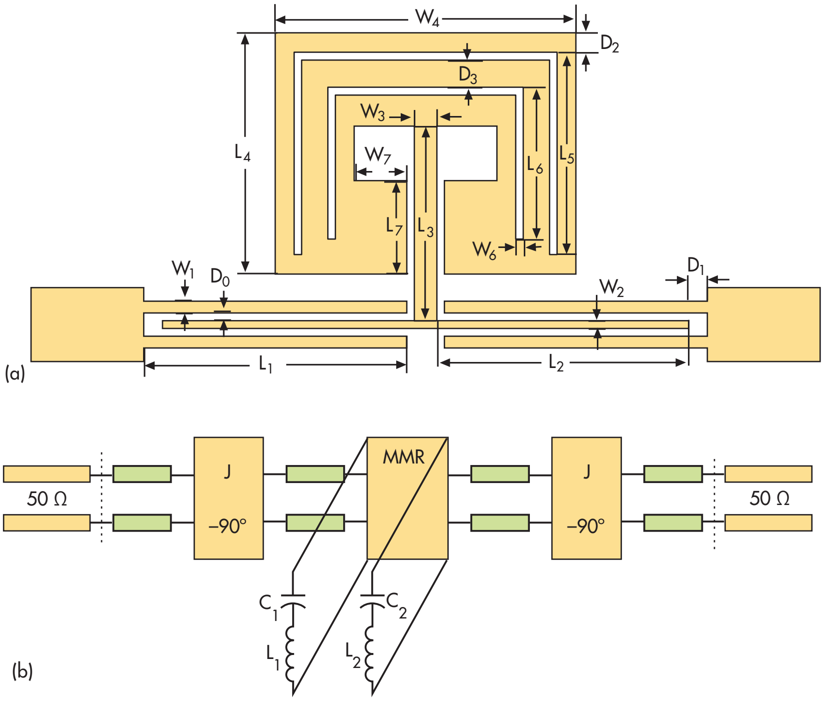
UWB BANDPASS FILTER Features Dual Notches

This compact microstrip bandpass filter, aimed at ultrawideband-frequency applications, uses parallel U-shaped slots to achieve dual-notched frequency bands.

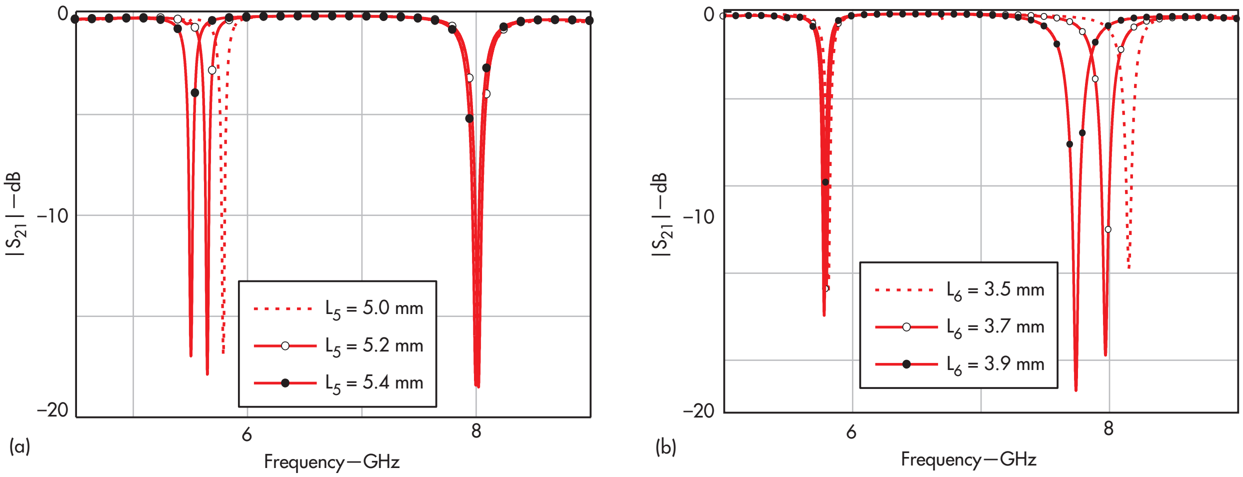
In 2002, the U.S. Federal Communications Commission (FCC, www.fcc.gov) authorized the use of license-free ultrawideband (UWB) signals from 3.1 to 10.6 GHz. The move swung the door open to applications such as high-data-rate wireless communications, high-accuracy radars, imaging systems, and indoor systems.[1]

As one of the essential components of a UWB system, UWB bandpass filters (BPFs) garner lots of attention. A number of the many methods already presented to design UWB BPFs[2-9] have taken on the challenges of supporting such a wide bandwidth. These methods include multiple-mode-resonator (MMR) filters,[2,3] defected-ground-structure (DGS) filters,[4,5] multilayer-coupled-structure filters,[6,7] and cascaded low- /high-pass filters.[8,9]

However, UWB systems cover very broad bandwidths, subjecting them to interference from many exist-



1. These diagrams show the configuration (a) and the equivalent transmission-line network (b) for the UWB BPF.



2. The simulated S-parameters for U-shaped slots have different values of filter parameter L_5 (a) and L_6 (b).

ing wireless networks, including 5.8-GHz wireless-local-area-network (WLAN) systems and some 8-GHz satellite-communications (satcom) systems. To minimize the effects of interference, UWB BPFs with multiple notched bands are needed to reject the unwanted signals.[10-17] One step toward achieving desired band-notched performance levels in UWB systems involved evaluation of stepped-impedance resonators.[10-13] Unfortunately, these designs came up with only one notched band. As a possible solution, double open-circuit stubs were embedded into the middle layer of broadside-coupled, stepped-impedance resonators,[14] with folded stepped-impedance resonators vertically coupled to the second layer of the multiple-layer circuit design.[15]

This approach produced two notched bands in a UWB BPF circuit. However, using such a multiple-layer circuit structure would ultimately lead to increased fabrication costs and incompatibility with typical existing microwave integrated circuits (MICs). Some work yielded BPFs with dual notched bands,[16,17] but these filters offered relatively low selectivity and less-than-ideal rejection levels for the notched filter bands.

Seeking improvements, engineers designed and developed a new compact UWB BPF with dual notched bands and good selectivity. An initial E-shaped multiple-mode resonator (EMMR) was used to create a basic UWB BPF with a pair of transmission zeros appearing in the lower and upper stopbands to improve skirt selectivity. Then, two parallel U-shaped slots (USSs) were etched into the initial EMMR to obtain the dual notched bands with a high degree of adjustment freedom, but without increasing filter size. The UWB BPF features notched bands centered at 5.8 and 8.0 GHz. To verify the validity of the design approach, measurements and computer-simulated results are presented for comparison.

Figures 1(a) and (b) illustrate the configuration of the proposed UWB BPF with dual notched bands and its equivalent circuit network, respectively. *Figure 1(a)* shows two microstrip interdigital coupled lines and an initial EMMR with two embedded parallel U-shaped slots (USSs). The microstrip interdigital coupled lines provide sufficiently strong coupling in the desired UWB band.

As seen in the equivalent-circuit network for the proposed UWB filter *(Fig.1(b))*, it's possible to model the microstrip interdigital coupled lines as two single transmission lines at two sides and a J-inverter susceptance in the middle. The two parallel USSs etched into the initial EMMR can be considered as two shunt-series resonant branches.

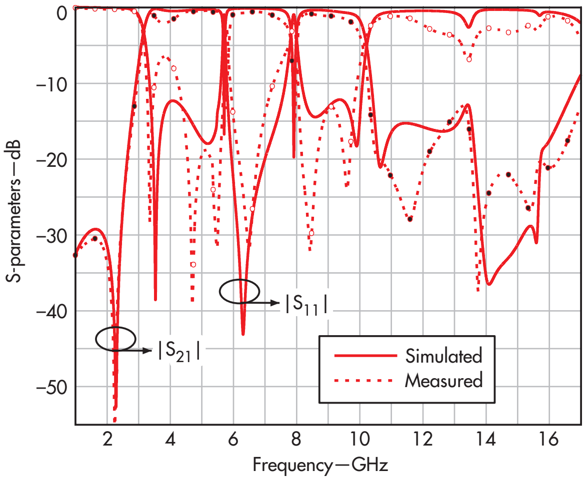
Adjusting the length of each USS, which is about one-half the wavelength of the desired frequency, tunes the center frequency of a notched band. Essentially, each USS is a half-wavelength resonator. To postulate the resonant frequency, refer to Eqs. 1 and 2:

$$f_{notch\text{-}lower} = c/[\lambda_{notch\text{-}even}(\varepsilon_{eff})^{0.5}] = c/[(2W_5 + 4L_5)(\varepsilon_{eff})^{0.5}] \quad (1)$$

$$f_{notch\text{-}upper} = c/[\lambda_{notch\text{-}even}(\varepsilon_{eff})^{0.5}] = c/[(2W_6 + 4L_6)(\varepsilon_{eff})^{0.5}] \quad (2)$$

where:

f_{notch} is the center frequency of the notched band;
λ_{notch} is the corresponding wavelength;
ε_{eff} is the effective dielectric constant;
and c is the speed of light in free space.



3. The plot compares measured and simulated S_{21} and S_{11} parameters for the fabricated UWB filter.

To validate the resonant properties, the frequency characteristics of USSs with various dimensions were simulated with Version 11.0 of the High Frequency Structure Simulator (HSFF) electromagnetic (EM) simulation software from Ansoft/ANSYS (www.ansys.com; *Fig. 2*). The frequency locations of the lower notched bands move downward in frequency with increases in the dimensions of L_5.

However, with decreases in the dimensions of parameter L_6, only the resonant frequency of the upper notched band moves upward. To obtain the desired frequencies for the notches, $f_{notch\text{-}lower}$ can be tuned by adjusting the length of L_5; varying the length of parameter L_6 controls $f_{notch\text{-}upper}$. The two notched bands can be independently tuned for desired notch frequencies.

The UWB BPF with dual notched bands was fabricated on RT/duroid 5880 printed-circuit-board (PCB) material from Rogers Corp. (www.rogerscorp.com). The PCB material features a relative dielectric constant of 2.20 in the z-axis, measured at 10 GHz, with a thickness of 0.813 mm and loss tangent of 0.0027.

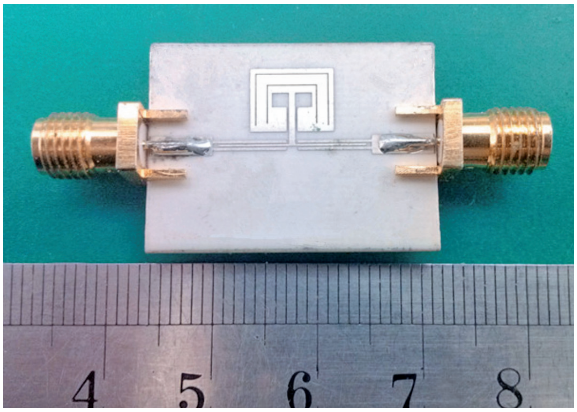
The optimal structural parameters for the UWB filter circuit (as illustrated in *Fig. 1*) were selected as follows: $L_1 = 7.0$ mm; $L_2 = 6.7$ mm; $L_3 = 5.0$ mm; $L_4 = 6.2$ mm; $L_5 = 5.1$ mm; $L_6 = 3.8$ mm; $L_7 = 2.4$ mm; $W_1 = 0.3$ mm; $W_2 = 0.2$ mm; $W_3 = 0.6$ mm; $W_4 = 8.0$ mm; $W_5 = 7.0$ mm; $W_6 = 4.8$ mm; $W_7 = 1.4$ mm; $D_0 = 0.1$ mm; $D_1 = 0.5$ mm; $D_3 = 0.6$ mm; and $D_4 = 0.1$ mm.

The fabricated UWB BPF with dual notched bands was measured with the 8722ES vector network analyzer (VNA)

"To minimize the effects of interference, ultrawideband badpass filters with multiple notched bands are needed to reject the unwanted signals."

from Agilent Technologies (now Keysight Technologies; www.keysight.com). The simulated and measured S-parameters for the filter are in close agreement *(Fig. 3)*. As The UWB BPF's passband, which ranges from 3.2 to 10.3 GHz, has an upper stopband with 10-dB attenuation through 17 GHz. Return loss is better than 15 dB across most of the passband.

For the two notched bands, insertion losses of more than 15 dB were measured at 5.8 and 8.0 GHz. The measured 3-dB fractional bandwidths (FBWs) for these two notched bands were 1.1% at 5.8 GHz and 1.2% at 8.0 GHz. Two transmission zeros were achieved around 2.3 and 11.6 GHz, improving the frequency selectivity and out-of-band performance. Some deviations between the measurements and the simulations were expected, due to factors such as reflections from the SMA connectors and the finite loss capabilities of the substrate circuit material. *Figure 4* shows the fabricated UWB BPF with dual notched bands, which measures a mere 20×27 mm^2.



4. The fabricated UWB filter with dual notched bands features compact 20×27 mm^2 dimensions.

The microstrip ultrawideband bandpass filter offers good passband and rejection-band performance levels in a fairly compact structure. It provides tenability of the notch bands and should be an attractive option for modern UWB communications systems, thanks to its simple structure, compact size, planar implementation, and high performance. mw

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