

7.1.2.2 Stepped-Impedance Line Filtering

The narrowband resonant structures of the previous section provide excellent frequency notch filtering responses with rejection of as much as 20dB. The techniques of Section 7.1.2.1 work well as band stop filters but do not readily provide low pass or other filter responses. Stepped-impedance line filtering opens new opportunities for spectral control of antennas [7].

A high-impedance transmission line (for instance, a wide slot line) electrically equates to a series inductor. A low-impedance transmission line (for instance, a narrow slot line) electrically equates to a parallel capacitor. By combining the electrical equivalents of series inductors and shunt capacitors, a low pass filter can be created. The range between a high and a low impedance achievable with a particular transmission-line geometry determines the efficacy of filtering. A large range in impedance allows for compact, electrically short filtering. In the context of transmission lines, stepped-impedance filtering is well understood and often discussed in textbooks [8]. This technique has not apparently been applied to antennas until recently.

One possible reason is that it remains difficult to achieve a very low impedance using a traditional slot line. If, however, the slot line is formed by metallizations on opposite sides of a dielectric, the slot width can be reduced to zero or even made to overlap. This yields a very low impedance. Opposing metallization slot lines allows one to benefit from the advantages of a slot line transmission line while also being able to achieve a low-impedance transmission line suitable for use as a stepped-impedance transmission line filter. For instance, consider the slot element of Figure 7.7(a). The wide and narrow slot line sections electrically equate to a four-element filter comprising two inductors and two parallel capacitors, shown in Figure 7.7(b). This circuit constitutes a fourth-order low pass filter.

Table 7.2

Example Sixth-Order Stepped-Impedance Low Pass Filter

Phase Angle at 5.9GHz (°)	Z(Ω)
6.9	8.62
36.8	376.7
11.4	4.8
78.8	376.7
14.1	52.4
92.7	376.7

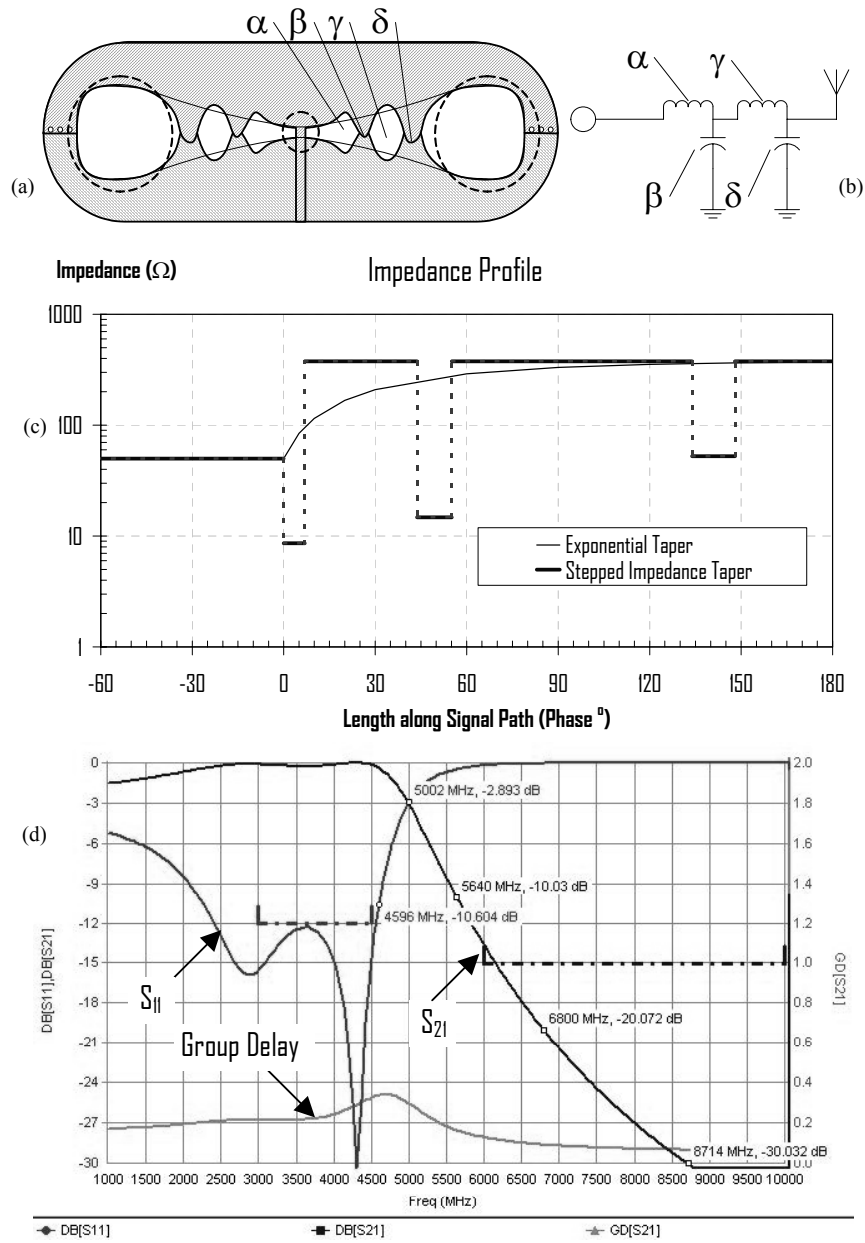


Figure 7.7 (a) A stepped impedance UWB slot antenna with a four pole low pass response, (b) equivalent circuit, (c) an impedance profile to yield a six pole low pass filter response, and (d) an Eagleware Genesys simulation of a six pole stepped impedance antenna low pass filter response (Courtesy: Next-RF, Inc., Huntsville, Alabama).

Figure 7.7(c) shows an impedance taper for a potential sixth-order low pass filter implementation. Table 7.2 presents the exact parameters. Impedance is stepped along 241° at 5,900MHz. This yields an electrical length of 34mm in free-space, less in a dielectric. The stepped-impedance filter of Figure 7.7(c) (and Table 7.2) has the low pass spectral response of Figure 7.7(d). Return loss, or S_{11} , is -12dB or better in the pass band from 3,000–4,500MHz. The 3-dB point is 5,000MHz, and the through response, or S_{21} , is down -10dB by 5,640MHz. This excess out-of-band rejection does not need to be provided by a front-end RF filter. The group delay is not excessive.

Of course, one may also inductively or capacitively load an antenna using discrete components, but using variations in the antenna transmission line or other variations in antenna metallization is preferred for reasons of cost and simplicity. The antenna essentially represents a fixed cost, and the techniques discussed in this section allow for clever modifications of the antenna to replace or eliminate discrete components in a matching filter, reducing overall system cost, manufacturing cost, system size, and system complexity.

Antennas are inherently high pass filters. Using stepped-impedance filter techniques, one may insert a low pass response into an antenna. Although the series inductor and shunt capacitor behavior of stepped impedance filters is ideal for low pass filter responses, these techniques may be applied to other filters as well. In particular, stepped impedance techniques can help a UWB antenna improve matching by allowing construction of a broadband impedance matching network.

7.1.3 Antennas and Spectral Control

Antenna spectral control is an important and often overlooked aspect of UWB system design. Designers are accustomed to working with narrowband systems in which the flaws of an antenna may be rectified by an easily implemented matching network. UWB matching networks are a last resort, not first aid. Ideally, a UWB antenna should be designed so as to cooperate with the RF front end to achieve a desired spectral result. Figure 7.8 illustrates this interplay.

The Golden Rule of UWB antenna design is

$$P_{TX}(f) G_{TX}(f) = \text{Mask}(f) \tag{7.1}$$

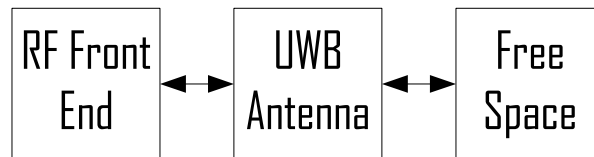


Figure 7.8 RF front ends and UWB antennas work together to define the overall system response.