for the preferred prototype studied in Figure 2. An antenna gain level of about 2.4–3.0 dBi over the UMTS band is obtained. Good radiation efficiency is also obtained, and it is found to be in the range of about 74% to 90% from the simulated results obtained from Ansoft simulation software HFSS [11].

4. CONCLUSION

A shorted patch antenna integrated with a U-shaped shielding metal case for operation as an internal mobile phone antenna having an EMC property with nearby electronic components has been proposed and studied. The proposed design applied to a smart phone or PDA phone has been successfully implemented, and the EMC property was obtained due to the presence of the U-shaped shielding metal case, in which the nearby electronic components can be accommodated. Good radiation characteristics of the proposed EMC internal antenna have also been obtained.

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DESIGN OF MICROWAVE LUMPED AND TRANSVERSAL BANDPASS FILTER WITH NOISE REDUCTION

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ABSTRACT: *A simple design technique for a microwave lumped and transversal filter using constant-k filter sections is presented. The noise figure can be suppressed by source degeneration inductors, which are added to the transversal element. The filter elements are analytically derived based on the specification and the noise minimization.* © 2006 Wiley Periodicals, Inc. Microwave Opt Technol Lett 48: 1161–1164, 2006; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.21551

Key words: *transversal filters; noise reduction; constant-k filter, source degeneration inductor*

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1. INTRODUCTION

For dynamic-range improvement in modern communication transceiver, noise analysis for RF/MW active bandpass filter has been studied recently [1–3]. In fact, the noise figure of an active inductor active filter can be as high as 9.1 dB, as reported by Adams and Ho [4]. The negative-resistance-based active filter and recursive ones have reported 7.5- and 5.5-dB in-band noise figures, respectively [5, 6]. But the noise-figure reduction approach is still rare. Recently, Cheng et al. have analyzed the noise of the negative-resistance-based active filter and derived its reduction scheme [3], but the filter stability concerns the above active filter architectures. To tackle filter instability, the lumped and transversal filter can be used, but it also exhibits poor noise performance [7]. In order to elevate the dynamic range of the above transversal filter, its noise performance was studied in [8], and a suppression scheme based on source-degeneration inductors was proposed in [9]. However, a filter systemat design which considers noise reduction is not yet developed. In this paper, we determine the filter's basic elements by its specifications, such as center frequency f_0, bandwidth BW, and so forth. To facilitate the above study, this work presents a design methodology for the lumped and transversal bandpass filter using a constant-k filtering structure.

2. DESIGN OF MICROWAVE LUMPED AND TRANSVERSAL FILTER

Figure 1 shows the basic structure of the conventional lumped and transversal bandpass filter; it consists of a low-pass filter section and a high-pass filter section. The bandpass response is achieved by the cascade of these two filter sections, which act like the delay and advance lines, respectively. Then, the filter band-edges are sharpened by the signal cancellation resulting from transversal elements (M_n, $n = 1, \ldots N$) [7]. These transversal elements are generally designed with weighted gains.

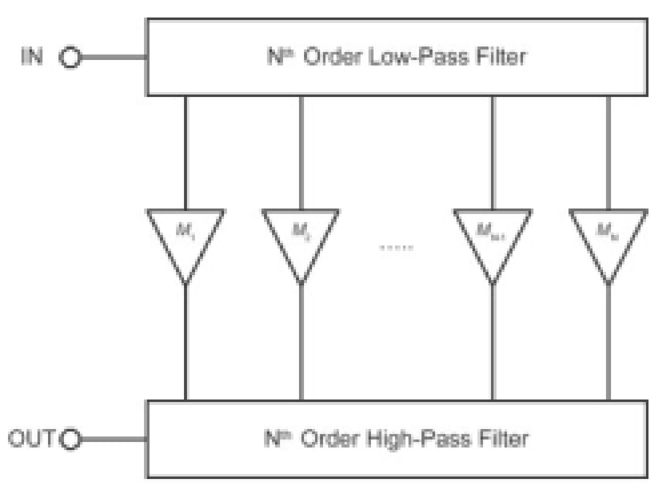

Figure 1 Conventional lumped and transversal filter

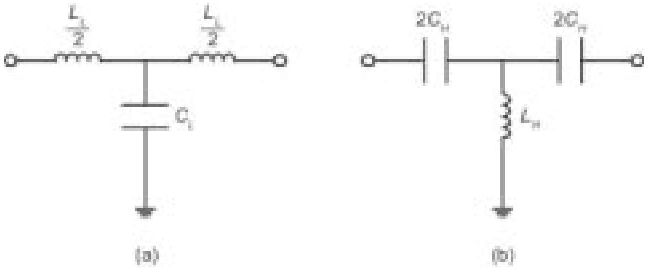

Figure 2 Low-pass (a) and high-pass (b) constant-k filter sections

2.1. Constant-k Low-pass and High-pass Filters

To construct the lumped and transversal filter, the low-pass and high-pass filter sections are designed to provide the basic bandpass response. Compared with the common insertion-loss method, identical inductive and capacitive elements in each section can be used for constant-k filtering and this may lead to much simpler MMIC implementation. The low-pass constant-k section is formed by two series inductors of equal value with a shunt capacitor, while the high-pass constant-k section consists of two identical capacitors in series and a shunt inductor, as shown in Figures 2(a) and 2(b), respectively [10]. It is easy to show that these constant-k sections have equal input and output image impedances because of the symmetry of the networks.

Thus, the image impedance Z_i of the constant-k section can be defined as

$$Z_i = R_o \sqrt{1 - \left(\frac{f}{f_c}\right)^2}, \tag{1}$$

where R_o is the nominal characteristic impedance and f_c is the cutoff frequency.

The nominal characteristic impedance $R_o(k)$ and cutoff frequency are determined by

$$R_o = k = \sqrt{\frac{L_L}{C_L}} = \sqrt{\frac{L_H}{C_H}} \tag{2}$$

and

$$f_c = \frac{1}{\pi\sqrt{L_L C_L}} = \frac{1}{4\pi\sqrt{L_H C_H}}. \tag{3}$$

Next, the element values for the low-pass and high-pass filter sections can be derived if the filter is specified by its center frequency f_0 and bandwidth BW as follows:

$$f_L = \frac{BW + \sqrt{BW^2 + (2f_0)^2}}{2}, \tag{4a}$$

$$f_H = \frac{-BW + \sqrt{BW^2 + (2f_0)^2}}{2}, \tag{4b}$$

$$L_L = \frac{k}{\pi f_L}; \quad C_L = \frac{1}{k\pi f_L}, \tag{4c}$$

$$L_H = \frac{k}{4\pi f_H}; \quad C_H = \frac{1}{4k\pi f_H}, \tag{4d}$$

where f_L and f_H are the low-pass and high-pass cutoff frequencies, respectively.

2.2. Lumped and Transversal Filter with Noise Suppression

In Figure 3, an N-section lumped and transversal filter with source degeneration inductors is depicted. The low-pass and high-pass sections are built by cascading the identical constant-k low-pass ($L_L C_L$) and high-pass ($L_H C_H$) sections, respectively. Then the basic bandpass response is achieved by cascading these low-pass and high-pass filter sections. The selectivity of the basic bandpass filter is controlled by the low-pass cutoff frequency f_L and high-pass cut-off frequency f_H. These parameters can be obtained from the bandpass filter specification, as given in Eqs. (4c) and (4d).

In addition to the above filter sections, the transversal elements (M_n, $n = 1, \ldots N$) are also used in the lumped and transversal filter, as illustrated in Figure 3. These transversal elements are implemented as a common source amplifier configuration, for example. With appropriate bias, the transmission zero can be introduced in the filter band-edges. To improve the transversal element noise performance, source degeneration inductors (L_{sn}, $n = 1, \ldots N$) can be used. Due to this inductive feedback, the current gain is reduced so as to lower the noise figure of the amplifier [11, 12].

It is reported that the transversal element M_N in the main signal component contributes the major portion of noise for a conventional lumped and transversal filter, and the overall noise figure of the filter can be analyzed by this transversal element alone [8]. Thus, the reduction of the noise figure of this traversal element is equivalent to the noise suppression of the whole lumped and transversal filter.

2.3. Source Degeneration Inductor Determination

The filter's noise figure is dominated by the transversal element in the main signal path. As in [11, 12], the noise reduction implies the impedance matching between this transversal element M_N and its associated input low-pass filter section. In Figure 3, the inductor L_{LN2} is the last element of the input low-pass filter section and it can be considered as the first element, which connects to the input of the common-source amplifier-based transversal element. Based on this configuration, input impedance Z_{in} seen at L_{LN2} for the transversal element can be expressed approximately as follows:

$$Z_{in} \approx s\left(\frac{L_{LN2}}{2} + L_{SN}\right) + \frac{1}{sC_{gsN}} + \left(\frac{g_{mN}}{C_{gsN}}\right)L_{SN}, \tag{5}$$

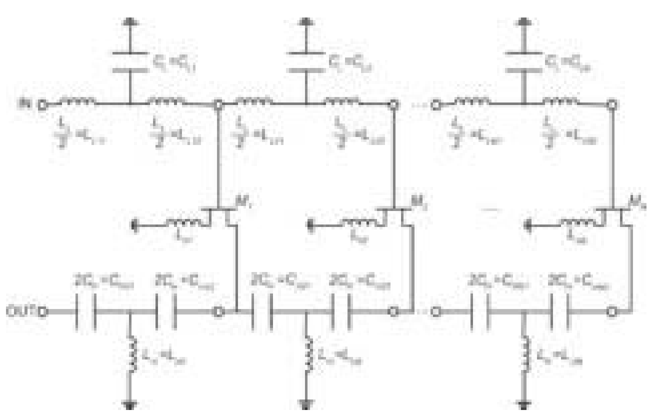

Figure 3 An N-section lumped and transversal filter with source-degeneration inductors

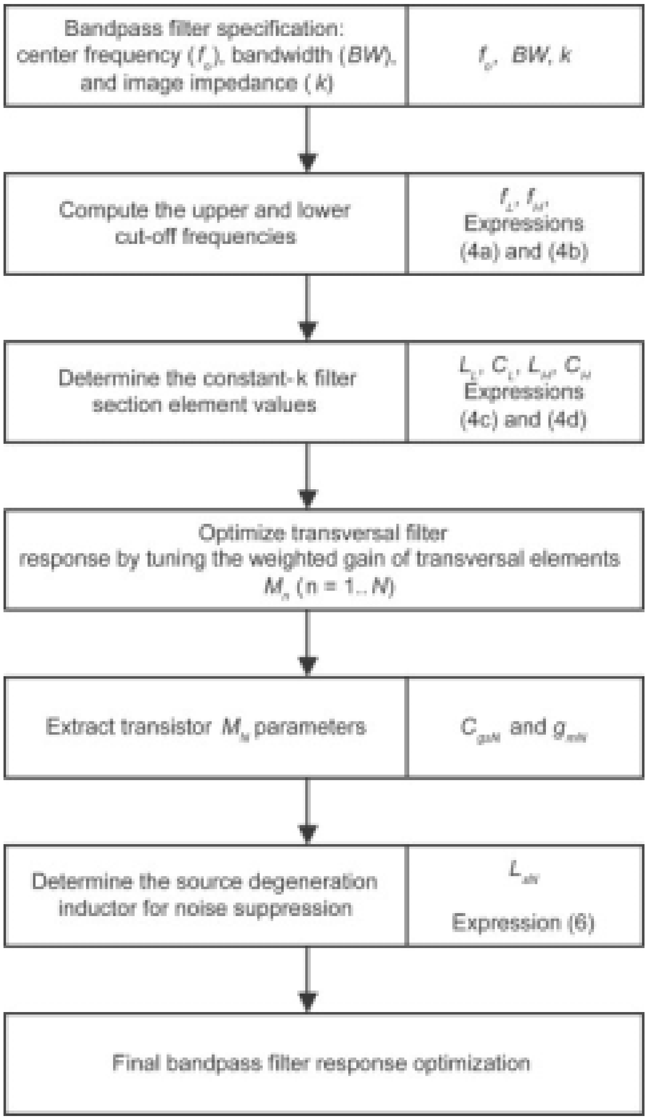

Figure 4 Systematic design diagram for the transversal bandpass filter using constant-*k* filter sections with noise consideration

where C_{gsN} is the gate-source capacitance of element M_N and g_{mN} is the transconductance of element M_N.

By using the power-match condition, the minimized noise figure is analyzed. As such, the needed source degeneration inductor for the above noise reduction is determined as

$$L_{sN} \approx \frac{\alpha}{2}\left[\sqrt{1+\frac{k}{\alpha^2\pi^2 f_0^2 g_{mN}}}-1\right], \tag{6}$$

where

$$\alpha = \frac{k}{\pi(\sqrt{BW^2+4f_0^2}+BW)}.$$

Together with Eqs. (4) and (6), the lumped and transversal bandpass filter with noise figure consideration can be designed by the systematic design sequence shown in Figure 4.

3. MEASUREMENT

To verify the proposed approach, a filter is designed and fabricated at $f_0 = 1.6$ GHz with 10% 3-dB BW and $k = 50\Omega$. This filter is

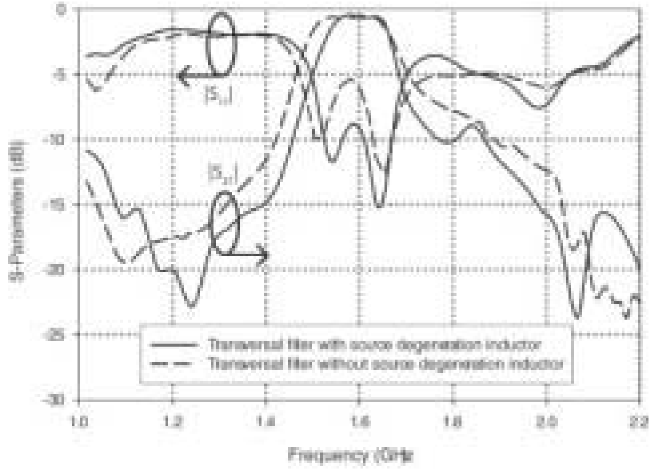

Figure 5 Measured $|S_{11}|$ and $|S_{21}|$ of lumped and transversal filter without source degeneration inductor (- - -) and with source degeneration inductor (—)

designed for the basic filtering response of the cascade of 6th-order constant-*k* low-pass and high-pass sections using Eq. (4). Two transversal elements (WJ FH101GaAs FETs) are used as the common-source amplifier. The source degeneration inductor L_{sN} is approximately determined by Eq. (6) and added to the main transversal element for noise reduction. Figure 5 shows the measured transfer characteristic of the filter with/without the source degeneration inductor. With the source degeneration element, overall filtering response is kept. The filter matching is still as good as 15 dB while the passband insertion loss is less than 1 dB.

Figure 6 shows the noise figure of the filters with and without the source-degeneration inductor. Obviously, the 5.6-dB in-band noise figure is recorded in the transversal filter without the source-degeneration inductor. The source-degeneration inductor is introduced and calculated by Eq. (6). Following some optimization trials, a 1.5-nH inductor is used, leading to a 3.2-dB noise-figure improvement; thus, the in-band low-noise figure is reduced to the level of 2.4 dB.

4. CONCLUSION

In this work, a systematic design of the lumped and transversal filter with noise reduction has been presented. Using this design,

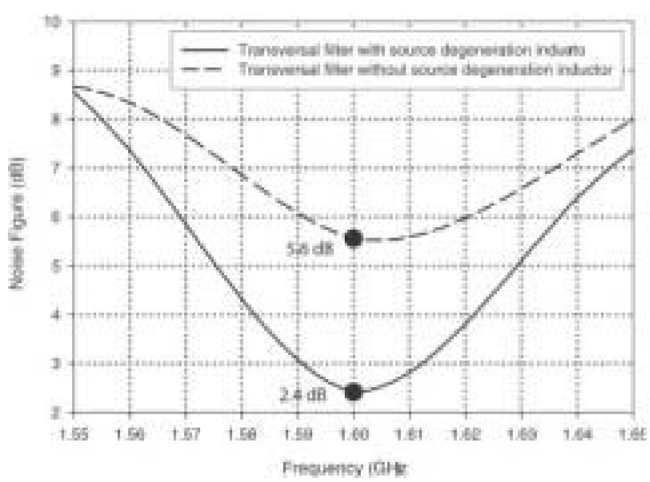

Figure 6 Measured noise figure of the lumped and transversal filter without source degeneration inductor (- - -) and with source degeneration inductor (—)

the basic bandpass filter sections can be designed with constant-k parameters. The source-degeneration inductor added to the transversal elements achieves filter-noise suppression. In addition, the basic filter elements, including the degeneration inductor, are determined by the filter specifications, for example, center frequency f_0, image impedance k, and bandwidth BW. For verification, we designed and experimented a 10% 3-dB BW L-band lumped and transversal bandpass filter. This prototype filter exhibited insertion loss within 1 dB and noise-figure suppression of 3.2 dB at the center frequency of 1.6 GHz.

ACKNOWLEDGMENTS

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THE DESIGN OF A DUAL POLARIZED QUASI-YAGI ANTENNA ARRAY

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ABSTRACT: *In this article, the design of a dual-polarized quasi-Yagi antenna array is described. The quasi-Yagi elements are fed by broadband microstrip-to-CPS balun. A feeding circuit that contains multiple Lange couplers is designed to feed a 2 × 2 array of quasi-Yagi elements. A 30% bandwidth (1.4 to 1.75 GHz) is achieved for VSWR and gain.* © 2006 Wiley Periodicals, Inc. Microwave Opt Technol Lett 48: 1164–1169, 2006; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.21550

Key words: *quasi-Yagi array; microstrip-to-CPS balun; Ansoft HFSS*

INTRODUCTION

The design of the dual-polarized quasi-Yagi antenna is motivated by the need for a broadband feed for reflector antennas. Some applications, such as reflector-based searching systems, require wideband antenna feeds to provide a large searching frequency band without the need to change feeds. To receive all of incoming signals, the antenna is required to possess the capability of distinguishing between two orthogonal senses of polarization (preferably circular). Another application is in satellite communications that transmitting and receiving of signals carried out with both circular polarizations. The quasi-Yagi antenna array is a promising

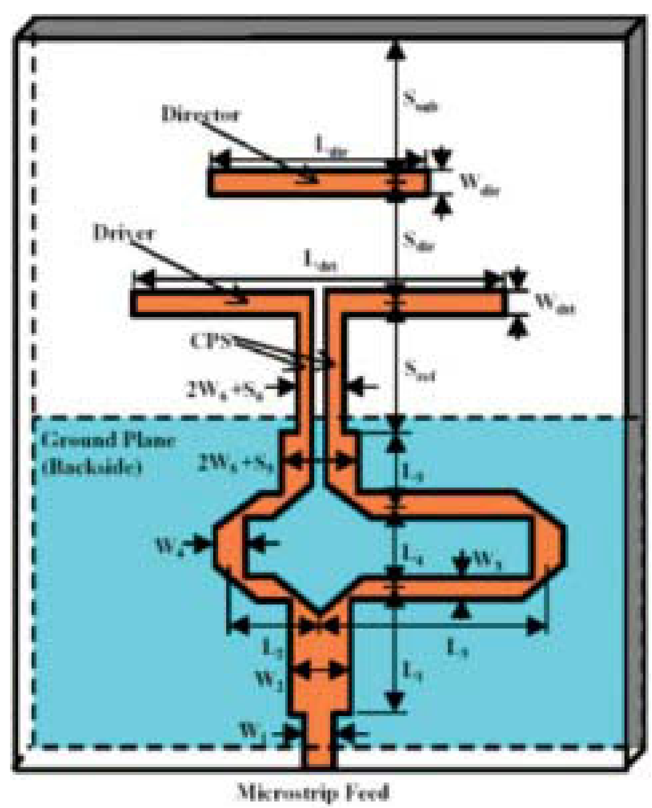

Figure 1 Schematic of a quasi-Yagi antenna. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]