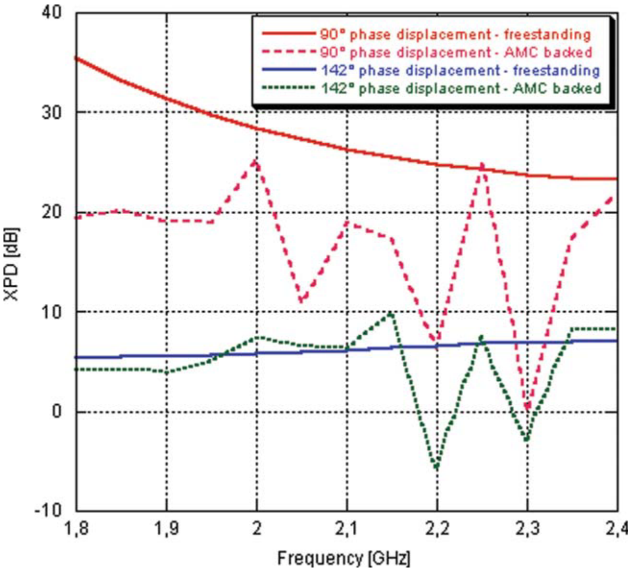

Figure 10 Comparison between the XPD of the dipoles, fed with a +90° phase displacement (perfect CP) and with a +142° phase displacement (EP), in freestanding configuration and in presence of the AMC screen. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

orthogonal dipoles fed with an opportune phase displacement, placed close to the surface.

Our intention is showing that the considered AMC does not enhance the CP properties of a radiating element different from the spiral due to the particular properties of the radiated field. In the first configuration, the dipoles are fed with a +142 degrees phase displacement. The chosen value is equal to the phase displacement between the θ and ϕ electric field components of the freestanding spiral. In this case, an elliptic polarization is radiated by the dipoles. The intention is to underline that again no improvement to the XPD is provided by the AMC. The case of +90 degrees phase displacement has been analyzed as well.

6. DIPOLES DESIGN

As the dipole is not a broadband antenna, we have designed it to resonate in the first AMC band, i.e., around 2.2 GHz.

To make a comparison with the spiral, dipoles have been placed at the same distance ($\lambda_0/18$) from the screen. Computations have been performed by using HFSS v.10.

In Figure 10, a plot of the XPD for the two analyzed configurations is given. In particular, we have compared the trend of the XPD in freestanding case with the one in presence of the AMC surface.

We can remark that the AMC does not provide any improvement for the CP properties of the dipoles. In fact, in both cases (+90° and +142° phase displacement), the XPD curve obtained in presence of the artificial magnetic surface oscillates around the maximum value reached in the freestanding configuration. By using the spiral, on the contrary, two noticeable spikes of XPD are visible at the AMC resonances in Figure 3. Moreover, in the same figure, a slight decrease of the XPD is apparent within the frequency regions far from the AMC resonances, owing to the perfect electric conductor (PEC) behavior of the screen, further proving that the circular polarization is given exclusively by the presence of the AMC screen.

7. CONCLUSIONS

An artificial magnetic conductor has been proposed that is able to efficiently convert an elliptic polarization into a circular one if conveniently excited. Indeed, an increase of XPD can be clearly observed at the AMC resonances (see Fig. 3). Moreover, a slight decrease of the XPD is apparent in the frequency regions far from the AMC resonance, owing to the PEC behavior of the surface, further proving that the circular polarization is given exclusively by the presence of the AMC screen.

ACKNOWLEDGMENTS

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A COMPACT DVB-H ANTENNA WITH VARACTOR-TUNED MATCHING CIRCUIT

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ABSTRACT: *A reconfigurable varactor-based matching circuit is proposed in this article. The introduction of an extra series inductor into the matching circuit reduces the required capacitance ratio of the varactor from 27.9 to 8.2. A meander line DVB-H antenna is designed and fabricated to verify the concept. The dimensions of the prototype antenna are 80 × 10 × 10 mm^3, and it can provide better than -10 dB return loss across the 470–770 MHz bandwidth.* © 2010 Wiley Periodicals, Inc. Microwave Opt Technol Lett 52: 1786–1789, 2010; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.25317

Key words: *reconfigurable antenna; varactor-tuned; compact*

1. INTRODUCTION

Digital Video Broadcasting-Handheld (DVB-H) service can deliver television programs or other multimedia content directly

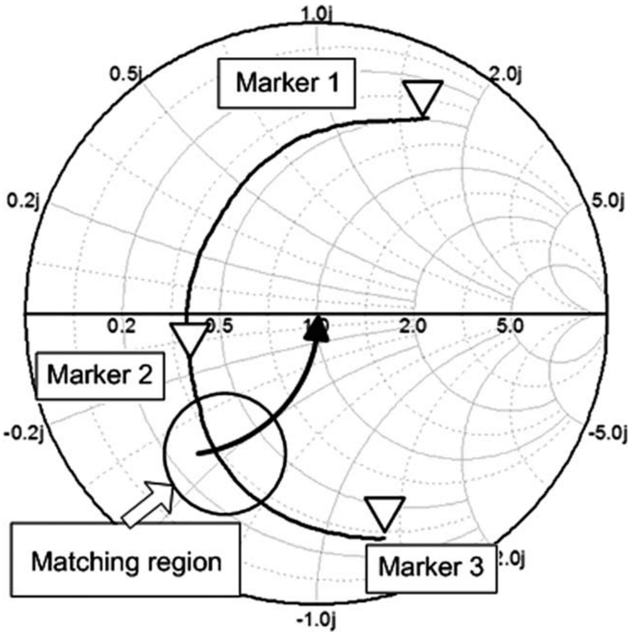

Figure 1 Impedance curve of the original antenna

to mobile terminals. DVB-H operates at the frequency range of 470–770 MHz, which covers a relative bandwidth of 48.4%. The typical dimensions of a handset are quite small in comparison to a quarter of wavelength at 470 MHz, so designing a passive internal DVB-H antenna to cover the whole band and provide good performance is always a challenge. One option is the use of dual-resonant lumped elements to enhance bandwidth [1], but this can only expand the bandwidth to a certain point. Another attractive solution is the frequency reconfigurable antenna [2, 3]. The working band of these antennas can be dynamically switched or tuned. Although the antenna can only cover a certain portion of the whole working band at any given time, it is able to provide full coverage when all working states are combined. In existing work, a variable capacitor (varactor) is utilized to change the electric characteristic of antenna element; RF switches and PIN diode are used to control the working length of the antenna to operate in different frequencies. Several designs have been proposed for DVB-H antennas in small devices [2, 3]. Compact in size, these designs can also deliver the necessary impedance bandwidth and gain level. The varactor in [2, 3] can continuously tune the antenna for a wider frequency range and better performance. Both antennas proposed in [2, 3] use a loading technique, loading the antenna by attaching a shunt varactor between the end of the antenna and the system ground. This limits options for the antenna element's form factor, since the antenna tail must be close to the system ground.

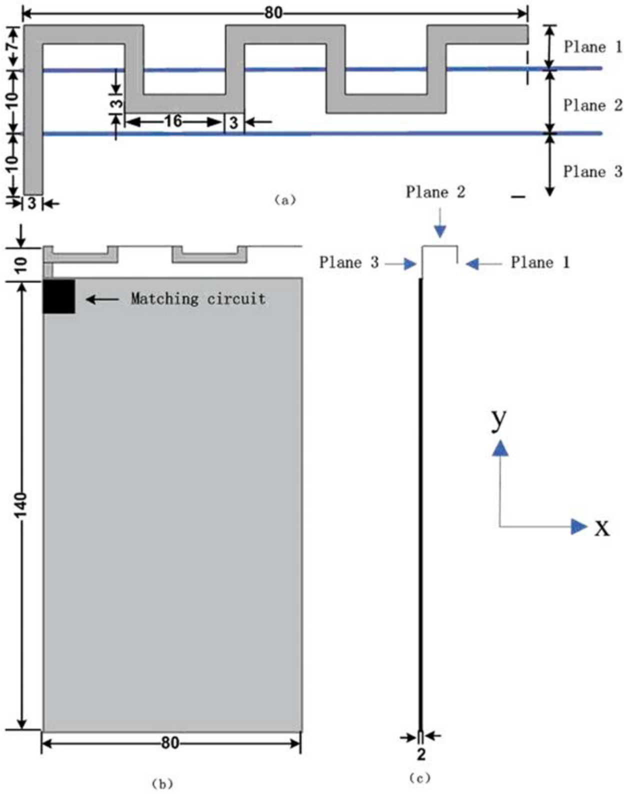

Figure 2 Geometry of mender line antenna: (a) Antenna element (b) Front view (c) Side view. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

This article proposes a new frequency-reconfigurable antenna based on a tunable matching circuit. To verify the concept, a meander line antenna element is designed to work with the matching circuit. Better than -10 dB measured return loss across the 470–770 MHz bandwidth has been achieved. The dimensions of the meander line element are $80 \times 10 \times 10$ mm^3. The matching circuit includes an extra series inductor, decreasing the required capacitance ratio of the varactor from 27.9 to 8.2.

2. MATCHING CIRCUIT DESIGN

To demonstrate the matching technique proposed in this article, a meander line antenna is used as a design example. In fact, the antenna element can be replaced by an antenna of any form factor, as long as it has similar frequency response. Figure 1 shows the impedance curve of the original antenna on a Smith Chart. Specific antenna dimensions can be found in Figure 2. Three markers on the curve, 1, 2, and 3, denote the lowest, middle, and highest working frequency, respectively. There are two considerations in designing a varactor-based antenna matching network. First, the capacitance ratio between the maximum and minimum capacitance which a varactor needs to provide must fall within a reasonable range. Second, the topology of the matching circuit should not be overly complex.

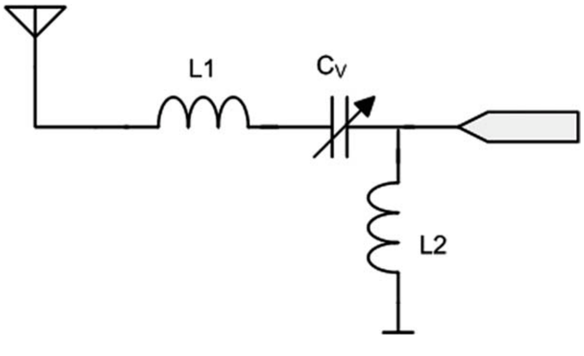

Figure 3 Diagram of matching circuit

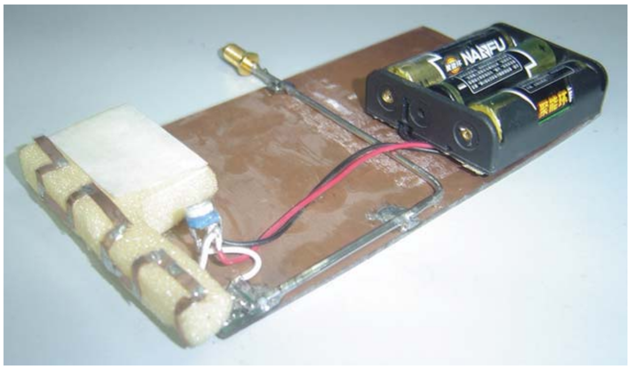

Figure 4 Fabrication of antenna. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

For the impedance curve shown in Figure 1, a range of impedance can be matched if the antenna is connected by a series varactor, then followed by a shunt inductor. The shunt inductor can move any impedance around the solid line circle area to the matching point, where the origin of the Smith Chart is. The series varactor can move other impedance between markers 1 and 2 into the solid line circle. Through the combined effects of the series varactor and shunt inductor, all impedance between markers 1 and 2 can be matched.

Parametric studies and optimizations lead to the conclusion that a meander line antenna element and a varactor with a capacitance ratio of 27.9 (25.1 pF/0.9 pF) are required to achieve the 470–770 MHz bandwidth. To decrease the capacitance ratio required by the varactor, a series inductor L1 is added to the matching network. The final matching circuit layout is shown in Figure 3.

For those impedances between markers 2 and 3 in Figure 1, the antenna has reasonable return loss and its reactance varies relative slowly when frequency changes. However, this segment of impedance is beyond the reachable tuning range of a matching circuit composed only of a series varactor and a shunt capacitor. With the addition of a series inductor, this segment of the impedance line is moved from the bottom side to the upper side of the solid line circle, and thus into the tunable range of the matching circuit. Simulations indicate that the addition of the extra series inductor reduces the required capacitance ratio from 27.9 to 8.2 (7.7 pF/0.94 pF).

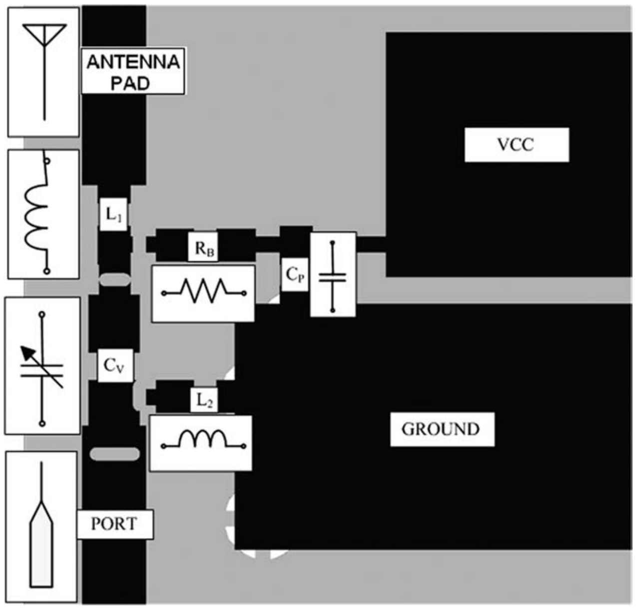

Figure 5 Layout of matching circuit

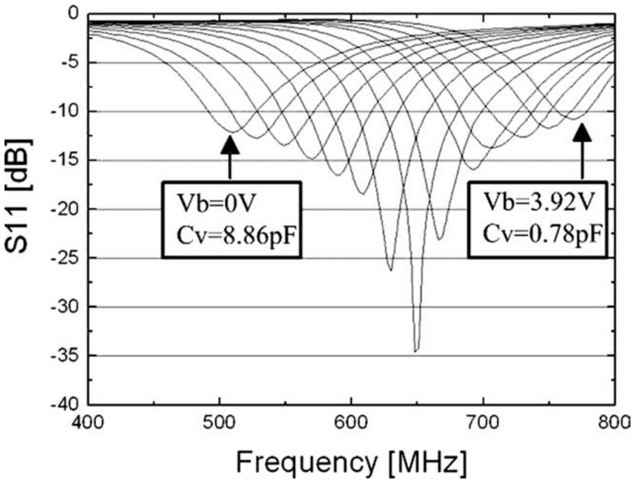

Figure 6 Measured return loss

3. EXPERIMENT RESULTS

To verify the concept of the varactor tuning matching network, a metallic meander line is selected as the antenna element. Specific dimensions are given in Figure 2 and its fabrication is shown in Figure 4. The antenna element is made of a flat metallic meander line. The element is folded and attached to the outer side of a foam support, whose dimensions are 80 × 10 × 10 mm^3. The antenna is installed on a single-sided FR4 board. The size of the board is 140 × 80 mm^2, with a thickness of 1.6 mm. The impedance of the antenna without matching is shown in Figure 1.

The proposed matching circuit is fabricated on a 10 × 10 mm^2 double-sided FR4 board shown in Figure 5. Most of the components labeled in Figure 5 correspond to Figure 3, with the exceptions of Rb and Cp, which are a bias resistor and bypass capacitor supplying bias voltage to the varactor. The varactor used in the experiment is Skyworks SMV1247-079. The series inductor L1 and shunt inductor L2 used in the experiment are 15 nH and 22 nH, respectively. The back of the matching circuit, a solid piece of copper and which also functions as the ground, is soldered to the big board. Voltage is supplied by three AA batteries. A variable resistor is used to adjust the bias voltage.

Figure 6 shows measured return loss of the antenna with the varactor bias voltage changes from 0 to 3.92 V. Clearly, it is possible for operating frequency to be continuously tuned and cover the whole DVB-H band with S11 better than −10 dB. Based on the specification sheet, the capacitance values are 8.86 pF and 0.78 pF at 0 V and 3.92 V bias, respectively. This represents a capacitance ratio of 11.3 rather than the 8.2 obtained in the simulation. It is believed that this discrepancy results from the imperfection of the varactor and parasitic reactance from lumped inductors and circuit board. Figure 7 shows the measured radiation patterns of proposed antenna at 520 and 720

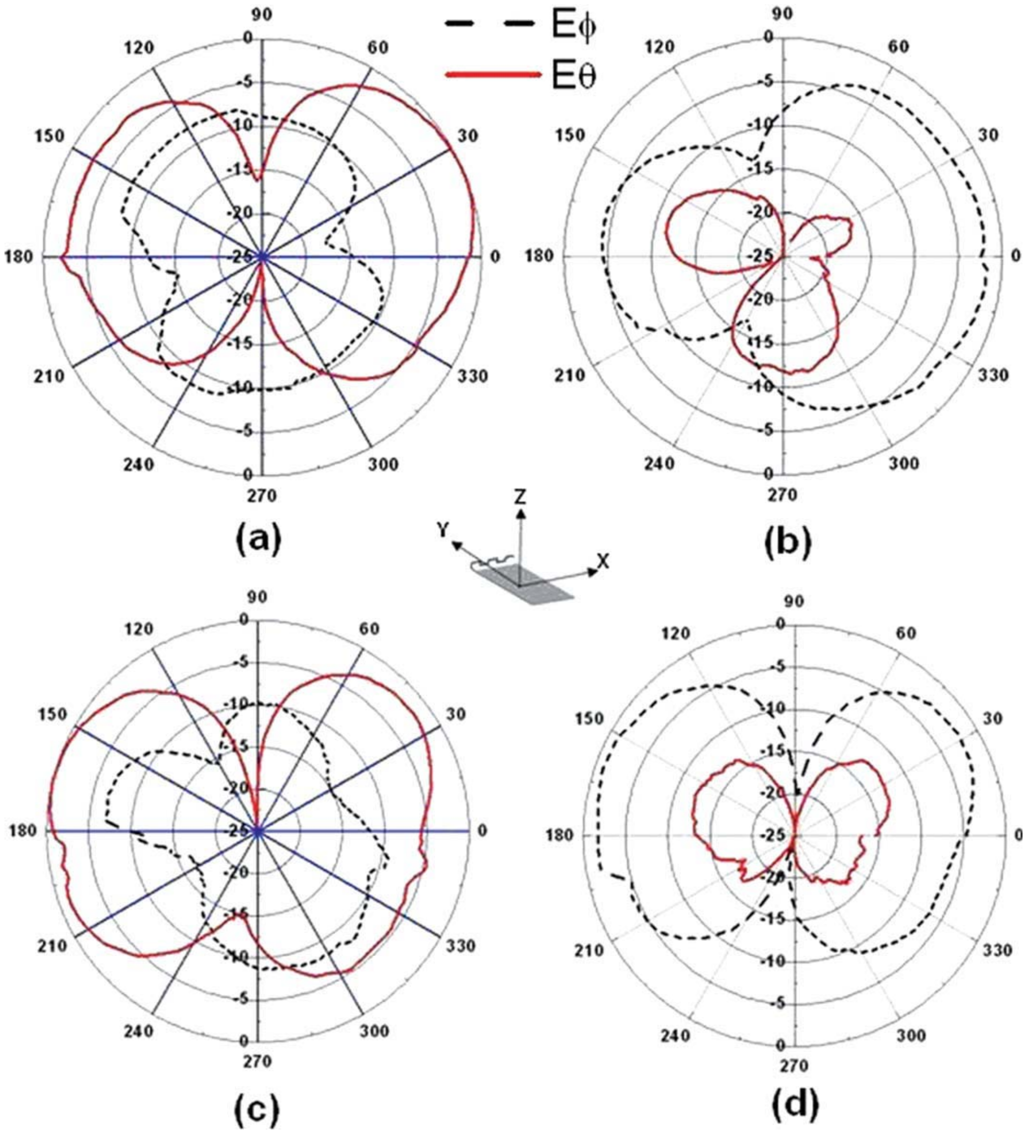

Figure 7 Measured radiation patterns: (a) *y–z* plane at 520 MHz (b) *x–y* plane at 520 MHz (c) *y–z* plane at 720 MHz (d) *x–y* plane at 720 MHz. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

MHz, a monopole-like pattern is achieved for vertical and horizontal polarization.

4. CONCLUSIONS

A compact meander line monopole antenna with varactor-tuned matching circuit for DVB-H application is proposed. The dimensions of the prototype antenna are 80 × 10 × 10 mm^3. The antenna provides good coverage over the 470–770 MHz bandwidth. The return loss over the entire bandwidth is better than −10 dB.

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