Progress In Electromagnetics Research Letters, Vol. 24, 1–8, 2011

FREQUENCY TUNABLE ANTENNA FOR DIGITAL VIDEO BROADCASTING HAND-HELD APPLICATION

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Abstract—In this paper, we present a frequency tunable antenna suitable for Digital Video Broadcasting Handheld applications. Due to the narrow operating frequency band of the antenna derived from a monopole coupled loop antenna, a tuning system has been proposed to sweep the narrow band on a large frequency range in order to cover the DVB-H frequency bandwidth [470–702] MHz. We provide results of this antenna mounted on a circuit board simulating a terminal handset.

1. INTRODUCTION

With the development of hand-held communication devices, such as Digital Video Broadcast-Handled (DVB-H), the needs for small and broadband antennas are ever demanding. The major challenges are the very broadband frequency range [470–702] MHz defined in the European standard and the necessity to embed antenna working in UHF band into the mobile handset. Several methods are proposed to solve these problems. In [1–3], broadband antennas are proposed for Digital Broadcast applications and are integrated, for example, in a folder type mobile phone or in a USB stick. For these antennas, impedance, gain and efficiency are compliant with the specifications. The second method to cover the frequency range of such broadband applications uses frequency tunable antennas. The basic antenna is then a narrow band one and the implementation of active devices introduces a frequency tunable ability. From a system point of view, it provides a frequency selectable function which improves the signal to noise ratio. In [4, 5], varactor diodes have been associated with PIFA

Received 5 April 2011, Accepted 12 May 2011, Scheduled 12 May 2011

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or meander antennas, and radiation patterns like S_{11} demonstrate antenna's performances. We also notice in [9, 10] that for such application the behavior of the antenna must be provided with the inclusion of the circuit board simulating the mobile handset. In this paper and based on [6, 7], we propose a frequency tunable antenna constructed with a varactor diode and a modified Monopole Coupled Loop Antenna (MCLA).

In the first part of this study, we introduce the modified MCLA and we give the antenna's behavior. For practical purposes, in this part the antenna is placed above a limited ground plane (300 mm × 300 mm). This antenna provides a narrow band operating frequency band (around 790 MHz). In the second part, we present an evolution of this antenna where the radiating element is associated to a parallel ground plane. This configuration simulates the behavior of the radiating element in presence of the mobile handset's circuit board. To cover the large frequency of DVB-H application, we investigate the ability to sweep the narrow band by introducing a frequency tunable system. The tuning method presented is based on locating a varactor diode directly in the antenna structure in order to continuously control the operating frequency with a DC bias voltage. As a result, a desirable frequency in a broadband frequency range covering [470–702] MHz is achieved.

2. A NARROW BAND ANTENNA DERIVED FROM MONOPOLE COUPLED LOOP ANTENNA (MCLA)

In Figure 1, we show the geometry of a MCLA loaded with inductor which is the basis of our work. In [6], we have demonstrated that a modified antenna with an open circuit provides size reduction. Unfortunately, this technique did not allow the antenna's size to be compatible with the mobile terminal's dimensions. It means that additional techniques should be inserted to achieve this goal.

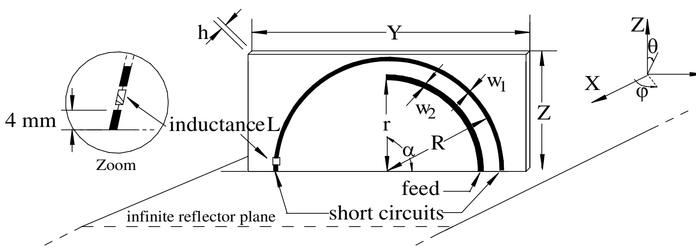

Figure 1. Geometry of the MCLA.

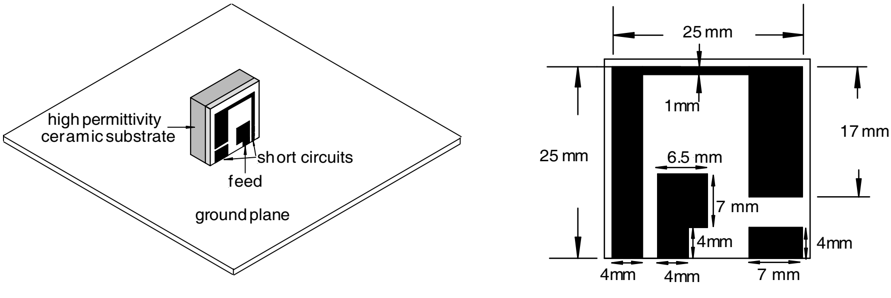

Figure 2. (a) Overview of the narrow band antenna represented by the association of a printed antenna and a ceramic substrate and (b) a zoom of the radiating element with its main dimensions.

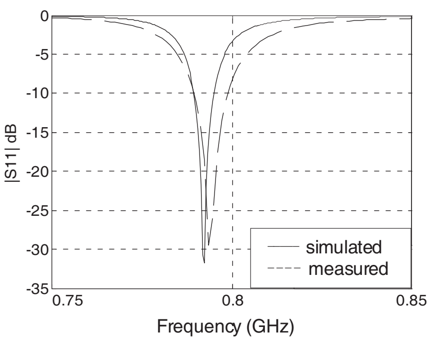

Figure 3. Return losses of the narrow band antenna derived from the monopole coupled loop antenna (MCLA) concept.

As a technique for reducing the volume of this antenna, we introduce a change in line width on the half loop part [8], and we associate the printed antenna to a high permittivity substrate (i.e., ceramic). An overview of the antenna structure with its main dimensions is shown in Figure 2. It is built on a 0.8 mm thick dielectric substrate (Neltec NY9300, $\varepsilon_r = 3$) associated to a ceramic substrate ($25 \times 25 \times 1.8$ mm, $\varepsilon_r = 20$). For the preliminary studies, the antenna is placed above a limited ground plane.

If we compare Figure 1 and Figure 2, it is easy to recognize that the circular half loop becomes a square one. We also notice that the method to feed the rectangular loop is still an electromagnetic coupling method with a small monopole with a specific P shape. As we mention at the beginning of this paragraph, an open circuit in the right side of the square loop provides a decisive contribution to size reduction.

A prototype was studied and manufactured around 790 MHz. Figure 3 shows the measured and simulated return losses. The simulated results are obtained using HFSS® Software (High Frequency Structure Simulator) and we notice a good agreement between the theory and the measurement. The frequency bandwidth is close to 10 MHz which is suitable for DVB-H reception, since one channel in a bandwidth of 8 MHz is received at a time.

3. FREQUENCY TUNABLE ANTENNA FOR DVB-H

To evolve through the mobile terminal applications, we modify the ground plane configuration. As depicted in Figure 4, the antenna described in Figure 2 is associated to a parallel ground plane and optimized in order to take into account the shape of the parallel ground plane.

Then, we include a varactor diode on the optimised square loop to control the resonant frequency with a DC bias voltage. As a function of this DC bias voltage, the varactor diode is associated with an inductor in order to realize a tuning inductor which changes the equivalent electrical length of the square loop. This mechanism could be used to slightly tune the resonant frequency of the antenna.

The varactor component used is a MACOM MA4ST2200 diode. The equivalent circuit proposed by the vendor is a series RLC circuit

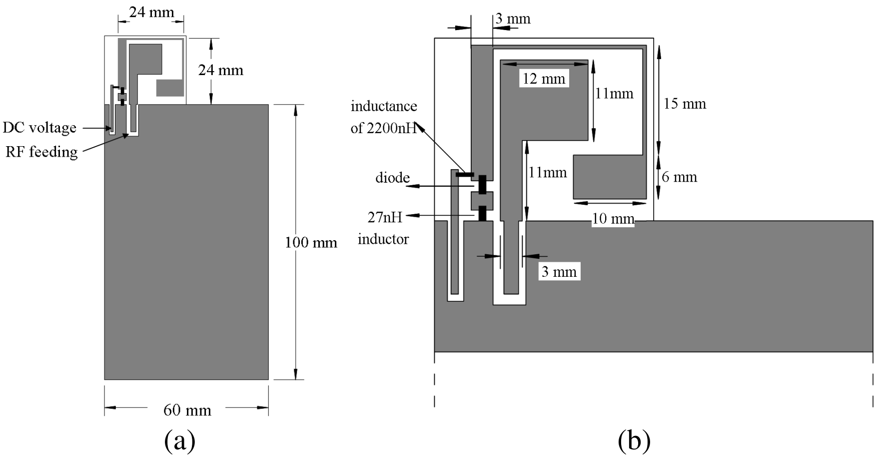

Figure 4. (a) Overview of the frequency tunable antenna with the circuit board simulating the mobile circuit board and (b) a zoom of the antenna with the DC bias circuit.

with a parallel capacitance (Figure 5). C_s is the tunable capacitor. The varactor has been characterized using a vector network analyzer, and then the equivalent circuit has been obtained through a de-embedding process.

Performances of this tunable antenna have been investigated using HFSS® software, substituting the diode by its equivalent circuit (Figure 5). For each voltage, we introduce a corresponding C_s, the other parameters (R_s, L_s, C_p) remain constant.

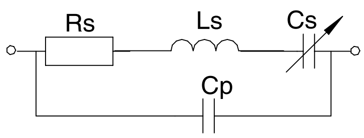

Figure 5. Equivalent circuit models of the varactor diode.

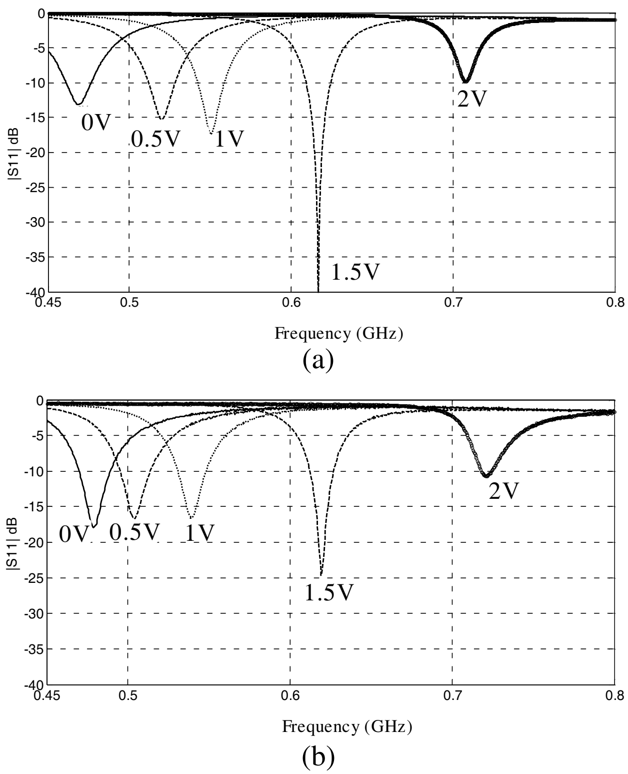

Figure 6. (a) Theoretical and (b) measured return losses (antenna Figure 4).

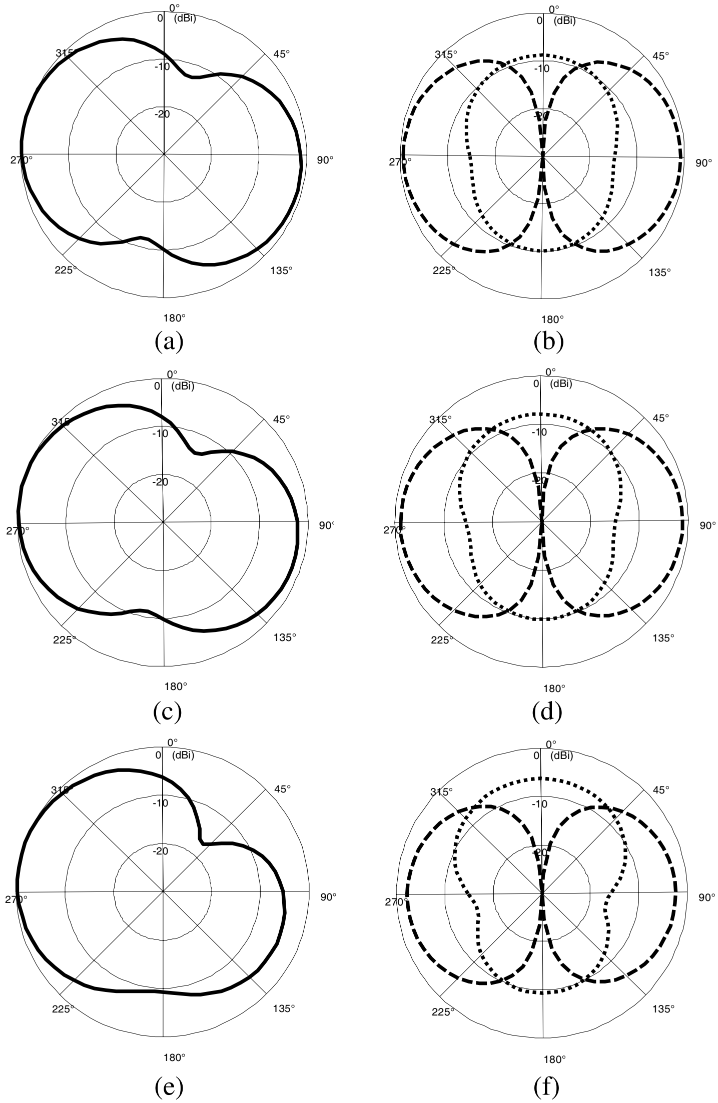

Figure 7. Theoretical radiation patterns. (a) DC voltage: 0 V, $f = 470\,\text{MHz}$, (—) $E\theta$ in YZ plane. (b) DC voltage: 0 V, $f = 470\,\text{MHz}$, (…) $E\phi$ and (- -) $E\theta$ in XZ plane. (c) DC voltage: 1.5 V, $f = 620\,\text{MHz}$, (—) $E\theta$ in YZ plane. (d) DC voltage: 1.5 V, $f = 620\,\text{MHz}$, (…) $E\phi$ and (- -) $E\theta$ in XZ plane. (e) DC voltage: 2 V, $f = 710\,\text{MHz}$, (—) $E\theta$ in YZ plane. (f) DC voltage: 2 V, $f = 710\,\text{MHz}$, (…) $E\phi$ and (- -) $E\theta$ in XZ plane.

In order to keep an operating frequency close to 470 MHz when the DC bias voltage is equal to zero, the parameters of the antenna depicted in Figure 4 have been optimized with the corresponding diode equivalent circuit characteristics. The bias circuit used to carry a DC control voltage to the varactor without interfering with the high frequencies currents is presented in Figure 4(b). The DC voltage is isolated from the RF signal by a Radio Frequency choke of 2200 nH, a series resistance of 5 kΩ and one chip capacitor of 5 nF.

The antenna performances have been computed for different DC control voltage values. Figures 6(a) and 6(b) show the measured and the theoretical return loss characteristics for a few voltage values. The frequency band is controlled by adjusting the variable capacitance of the varactor diode with the DC bias voltage. The range of this DC bias voltage is from 0 V to 2 V and is compatible with the output voltage of a mobile's battery

As shown in Figure 7, the antenna covers the [470–702] MHz frequency range which corresponds to a 39.5% relative −10 dB bandwidth. For each operating frequency except 702 MHz, the corresponding instantaneous bandwidth is more than 10 MHz. For the highest frequency (702 MHz), the instantaneous bandwidth is more than 10 MHz if we consider a S_{11} below −6 dB which is acceptable for a reception application. We can also notice a good agreement between theory and measurements.

Radiation properties were also computed for different DC bias voltages. The normalized radiation patterns are represented in Figure 7. For YZ plane (Figures 7(a), (c), (e)), we obtain a non-symmetric shape of radiation pattern due to the specific position of the radiating element on the circuit board.

To complete these results, we add that the theoretical gain starts from −9 dBi at 470 MHz up to −2.5 dBi at 702 MHz. Theses gains are compliant with the DVB-H specifications.

4. CONCLUSION

A varactor tuned antenna has been designed and realized. The aim of this study is to provide a simple technique to sweep the instantaneous bandwidth of a radiating element from 470 to 702 MHz. The main advantage of this tunable antenna proposed for DVB-H application is its suitability for mobile terminals. The effectiveness of the tuning ability has been demonstrated and measurements are found to be in good agreement with theory for the return loss. For completeness, other important requirements such as DC power consumption and DC bias voltage range compatible with the output voltage of a mobile's battery have been considered.

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