A compact and reconfigurable DVB-H antenna for mobile handheld devices

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***Abstract*— This paper presents a compact inverted F antenna which is dedicated to the Digital Video Broadcasting-Handheld (DVB-H) standard. This antenna is suitable to small mobile devices and the operating frequency is tuned with a hyperabrupt varactor diode component. The antenna dimensions are very small and it covers the entire DVB-H band going from 470 MHz to 862 MHz. Low cost, compactness, wide frequency range coverage and low frequencies are the main advantages of this antenna. Moreover, good performances are obtained in simulations and in measurements.**

I. Introduction

The general tendency of mobile handheld systems is the miniaturization of devices [1]. Thus, the reduction of the antenna size becomes an important challenge, especially if the targeted application is a low frequency standard as for the case of the Digital Video Broadcasting-Handheld (DVB-H) standard. Moreover, the latter has a 60% relative bandwidth going from 470 MHz to 862 MHz. This wide frequency band can be covered with electrically small antennas [2] but the global dimensions are too important to be integrated in a classical handheld device. In this paper, a small frequency tunable antenna is presented. It covers the entire DVB-H band thanks to a hyperabrupt varactor diode component. Let us notice that in the DVB-H reception, one channel of 8MHz-bandwidth is received at a same time. Due to the fact that the hyperabrupt varactor diode datasheet is given as a rough line and does not give multiple parameters, the chosen varactor has been characterized to know its real values. Its measured S parameters will be integrated instead of the diode in the CST Microwave Studio. Antenna simulated results considering both the varactor datasheet and the measured S parameters of the diode will be compared with the measured ones.

A first section will show the characterization of the varactor component. Then, the antenna design will be presented with its measured performances. This section will underscore that characterizing the varactor and integrating its data during the simulation allows, more precisely, predicting the measurements.

II. Hyperabrupt Varactor Diode Characterization

For a frequency tunable antenna, the S parameters of the varactor diode is necessary. The datasheet of the chosen hyperabrupt varactor diode specifies a capacity range between 0.2 pF and 2 pF for 0 to 22 Volts tuning voltage.

Nevertheless, these values are given as a rough line and the datasheet didn't give multiple parameters. The values for junction capacitance *Cj* and the quality factor *Q* are supplied by the manufacturer and are almost always specified at a low frequency, usually 50 MHz, and a bias voltage of –4 Volts. *Q* is defined by $Q = 1/\omega C_j R_s$. This formula can be used to calculate the series resistance *Rs* of the varactor model at the measured frequency, however at microwave frequencies additional losses often result in a significantly higher value for *Rs*. The value of *Rs* is sometimes assumed to be constant with reverse voltage and frequency. The Fig. 1 shows a widely used varactor diode model with *Lp* and *Cp* the values of the package inductance and capacitance. A much more accurate picture can be obtained by measuring the diode close to operating conditions and then choosing values for the lumped element model based on these measurements. Two important operating conditions are the frequency at which the diode is used and mounting method.

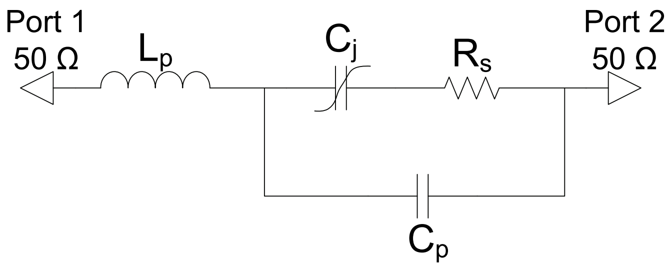


Fig. 1 Varactor diode model commonly used.

That's why, to reach an accurate antenna simulation and thus before the realization of the antenna, the hyperabrupt diode varactor component has been characterized. This one has been mounted on a 50 Ω transmission microstrip line as shown in Fig.2. Then, S parameters have been measured using a network analyser.

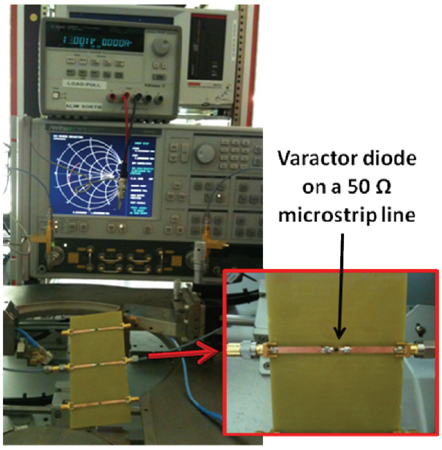


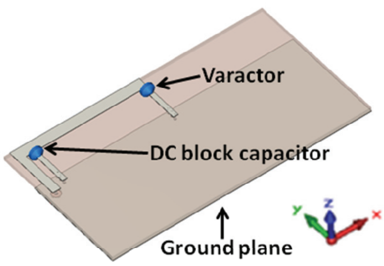
Fig. 2 Characterization of the hyperabrupt varacor diode.

Finally, S parameters in the varactor reference planes have been deduced from the measured S parameters in the SMA connectors reference planes thanks to the de-embedding of the lines and the connectors. These S parameters will be added as a lumped element model in the CST Microwave Studio antenna simulations. The antenna structure will be the subject of the following section.

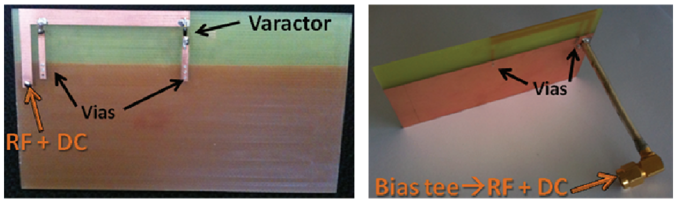
III. Antenna Design

The antenna structure presented in this paper is based on the IFA design [3]. Its structure is similar to a quarter wavelength monopole, where the top section has been bent to be parallel to the ground plane. This horizontal section involves a capacitive effect and then influences the input impedance. This effect could be compensated by adding a shorting line, that is to say a ground return. So, this shorting line allows adjusting the return loss because it involves a parallel resonance allowing setting the input impedance without adding any matching circuit.

Moreover, in order to decrease the global antenna dimensions, this one has been loaded by the varactor presented previously in order to enable tunable matching at different frequencies. The simulated and measured antenna structures are respectively presented Fig.3 (a) and (b). It is printed on a FR4 substrate (ε_r=4.9) and studied on a 90 mm x 35 mm ground plane. The global dimensions of the radiating element are $\lambda_0/32$ x $\lambda_0/14$ at 470 MHz.



(a)



(b)

Fig. 3 (a) Design of the simulated antenna (b) Design of the measured prototype.

The antenna is fed by a 50Ω coaxial cable, this one is fed by a Bias Tee. So, both the radiating element and the varactor are fed. Moreover, a DC block capacitor is needed between the radiating element and the ground as shown in Fig. 2. Indeed, it allows obtaining an open circuit for the DC voltage and a short circuit for the RF signal. The following section will deal with the simulated and the measured antenna results and the contribution of the second section, that is to say the characterization of the varactor diode component.

IV. Antenna Performances and Contribution of the Varactor Diode Characterization

This section deals with the comparison between the simulated and the measured results, the former being obtained thanks to the transient solver of CST Microwave Studio, while the latter being realized inside an anechoic chamber.

A. *S11 parameters for different polarizations of the varactor diode*

The Fig.4 presents the measured S11 parameters obtained for multiple polarizations of the varactor diode. Let us remind that one channel of the DVB-H band equals to 8 MHz. So, thanks to the capacity range, the antenna is matched on the entire DVB-H band going from 470 MHz to 862 MHz.

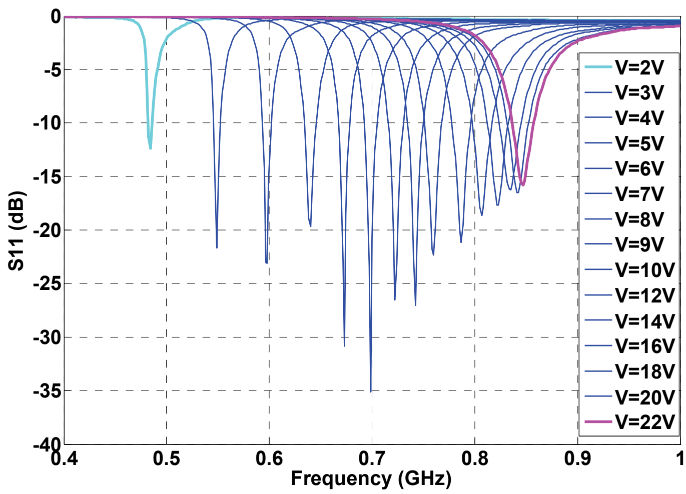


Fig. 4 Return losses for multiple polarizations of the varator diode.

To show the contribution of the varactor characterization, Fig.5 shows S parameters obtained for multiple varactor polarizations. In black, simulations with the varactor datasheet, in red, simulations with the data determined in the previous section and in blue, the measurements of the antenna. This figure clearly shows that the measurements are in a very good agreement with the simulations, when these ones are carried out with the real characterization of the varactor.

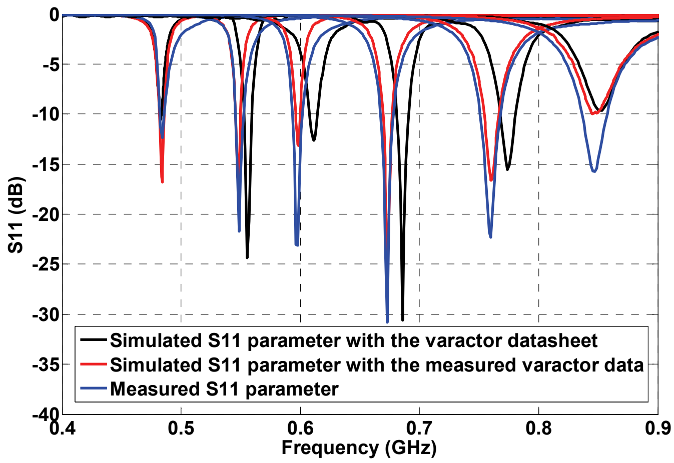


Fig. 5 Comparison between return losses.

B. *Realized gain on the DVB-H band*

Fig. 6 shows respectively the maximum realized gains and the return losses for the varactor diode polarizations respectively equal to V=2V (antenna matching at 470 MHz), V=6V (antenna matching at 673 MHz) and V=22V (antenna matching at 850 MHz).

The Fig. 7 sums up the maximum realized gain for many values of the diode polarizations. Let us notice that each value of the realized gain (presented on the Fig. 6) is identified at a given polarization when the antenna is matched. Remembering that the realized gain takes into account cable, connector and all antenna losses, it is defined as $G_r = (1 - |S_{11}|^2).G_{IEEE}$.

Thus, the diode varactor component and the DC block capacitor losses are taking into account in the realized gain. The 0 dB reference of the realized gain is an isotropic antenna, which is a perfect omnidirectional radiator. Moreover, the total efficiency is defined as the ratio of radiated to stimulated power of the antenna or the ratio of the realized gain defined previously to the directivity of the antenna.

This figure shows that the realized gain values (in red) are always greater than the ones required by the DVB-H application (in blue) despite of the varactor losses at this frequency range. So, the required specifications for this application (antenna matching and realized gain) are widely satisfied.

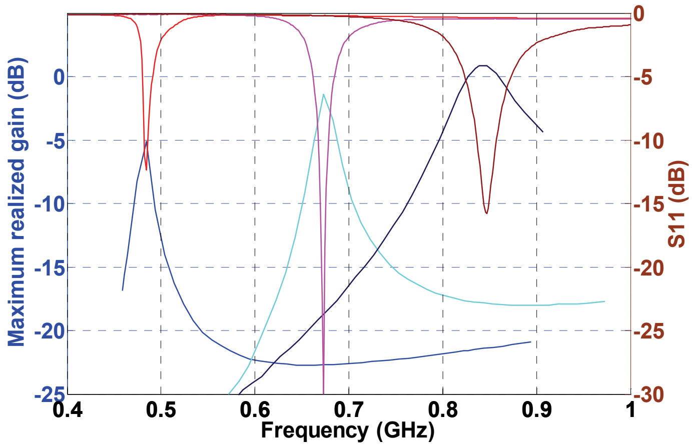


Fig. 6 Maximum realized gain and S11 for V=2V, V=6V and V=22V polarizations of the varactor diode.

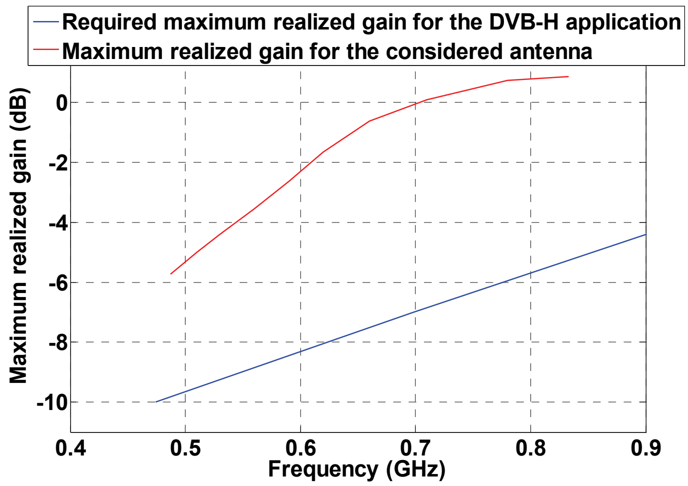
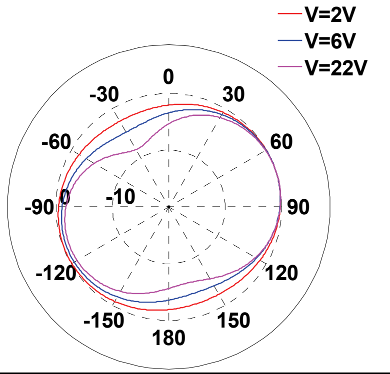
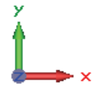
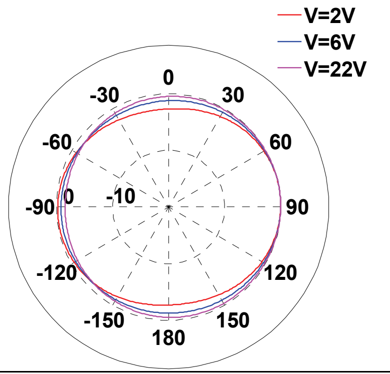
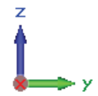
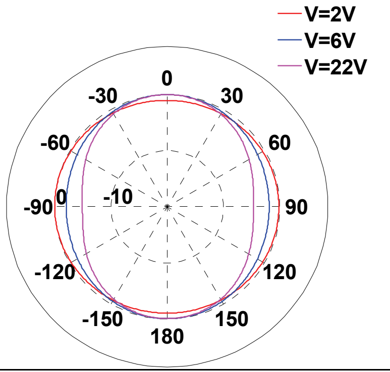
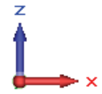


Fig. 7 Maximum realized gain on the DVB-H band.

C. *Radiation patterns*

The Table I shows the radiation patterns in the θ=90°, φ=90° and φ=0° planes, that is to say in the xOy plane (the one containing the ground plane), for three varactor diode polarizations V=2V, V=6V and V=22V. The maximum realized gain remains always higher than the one specified by the DVB-H application. Let's notice that it is lower at low frequencies due to the varactor losses and a lower impedance matching.

TABLE I
SIMULATED PATTERNS FOR THREE VARACTOR POLARIZATIONS IN THE Θ=90°, Φ=90° AND Φ=0° PLANES

θ=90°		
φ=90°		
φ=0°		

The shapes of these radiation patterns show omnidirectional patterns whatever the polarizations of the diode so, whatever the operating frequency of the antenna.

V. CONCLUSIONS

A compact inverted F antenna which is dedicated to the Digital Video Broadcasting-Handheld (DVB-H) standard has been presented in this paper. The antenna dimensions are very small ($\lambda_0/32$ x $\lambda_0/14$ at 470 MHz) and it is suitable to be integrated in all handheld devices. The characterization of the varactor diode has been done in a first time in order to predict more precisely the measurements. Finally, by changing the voltage of the hyperabrupt varactor diode, the antenna covers by a continuous shift (with a return loss lower than -6dB) the entire DVB-H band going from 470 MHz to 862 MHz. Moreover, its maximum realized gain meets the DVB-H specifications. Thus for all its performances and its small size, this antenna is a very good candidate for the DVB-H application.

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