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RECONFIGURABLE 460 MHz TO 12 GHz ANTENNA WITH INTEGRATED NARROWBAND SLOT

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Abstract—In the future, mobile handsets might incorporate more than 20 separate radios, creating a difficult antenna design problem due to the sever space restrictions. This paper proposes a reconfigurable wideband antenna, for use within clamshell mobile handsets. The impedance bandwidth of the new antenna was selected in order to meet current and future demands within the industry. It has been suggested that a portable Cognitive Radio must be capable of simultaneous communication (via a narrowband antenna) and spectrum sensing (via a wideband antenna). For this reason a narrowband slot antenna has also been integrated within the wideband radiator.

1. INTRODUCTION

A modern mobile phone typically contains more than 10 different radios (eg., penta-band cellular, GPS, WLAN, Bluetooth, FM radio, DVB-H) with more than 5 separate antennas [1]. In the future, mobile handsets will incorporate even more radios. The new radio functions could include: Radio Frequency Identification (RFID), Radio Direction Finding RDF, Cognitive Radio (CR) [2–4] and Ultra-wideband (UWB). In the traditional front-end architecture each radio is connected to a separate antenna element. For this reason a phone of the future might require in excess of 20 separate antenna elements [1].

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This is probably impractical due to limitations on the amount of space available within the handset. Several researchers have presented novel antennas to address the requirements of future radio systems [5–9]. This paper demonstrates a reconfigurable wideband antenna that can be switched between two different operating bands [10]. The first band ranges from 462 MHz to 1.51 GHz. 462 MHz lies just below the start of the Digital Video Broadcasting (DVB-H). The second band ranges from 1.31 GHz to frequencies in excess of 12 GHz. This is sufficient to cover the requirements of the Federal Communication Commission (FCC) UWB band.

The wideband antenna consists of a rectangular monopole having an elliptical base. If the antenna were used within a mobile handset front-end filters could be used to ensure adequate isolation between the different narrowband services. The filter would also be used to suppress out-of-band interference and prevent spurious emissions. A narrowband slot antenna has been integrated within the wideband radiator in order to address a possible requirement [4, 11] for simultaneous communication and spectrum sensing within a portable Cognitive Radio device. The narrowband slot antenna operates at 9.3 GHz. The operating frequency, for this antenna, can be varied using an external matching circuit.

2. STRUCTURE OF THE ANTENNA

The new device, show in Fig. 1, consists of an wideband disk monopole incorporating a narrowband slot antenna.

The slot antenna was inserted into the ground plane for the coplanar waveguide (CPW) feed-line. It is fed, from the underside, via a 15 mm long microstrip line. Although the results are not

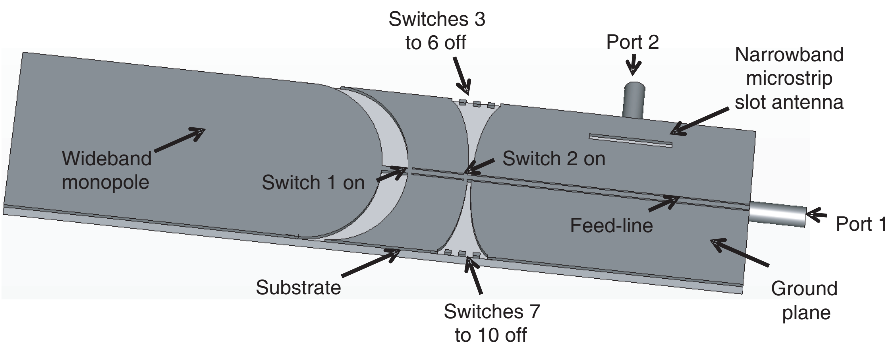


Figure 1. Structure of the antenna.

reported here, the operating frequency of this slot antenna can easily be adjusted using an external matching circuit. For this purpose it would be possible to employ a lumped element matching circuit. The design procedure for this type of matching circuit is well documented [12]. Recent papers have discussed the procedure for matching a narrowband patch antenna, using a lumped element external matching circuit [13, 14].

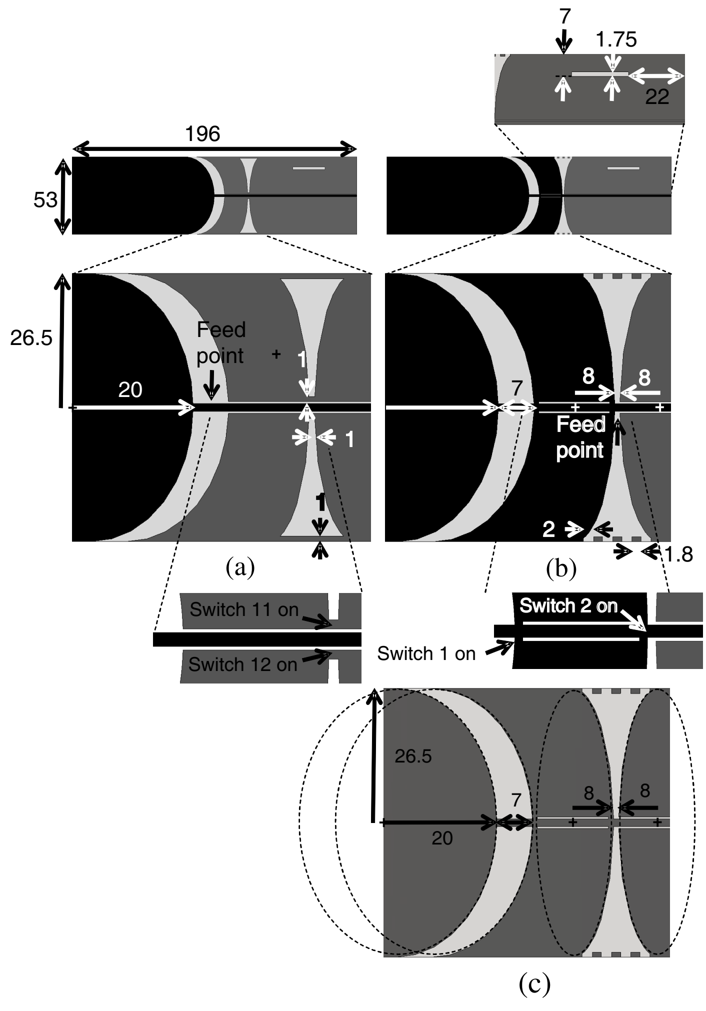


Figure 2. Circuit configuration required to operate within (a) mode 1, and (b) mode 2.

Wideband operation is obtained using a rectangular monopole, which is fed using a cpw line. The monopole has a convex elliptical base (see Fig. 2). The cpw ground plane also has an elliptical shape, in the vicinity of the feed point. By altering the direction of the elliptical curve, in the ground plane, from concave to convex it is possible to switch between a low and high frequency operating band. Fig. 2 shows how this is achieved. In each case the radiating monopole is shaded black, whilst the ground plane is shaded gray. This antenna configuration might be suitable for use within a clamshell phone. The hinge would be located at the feed point for the monopole antenna. Twelve microwave switches are employed in order to reconfigure between the two operating states, as detailed in Fig. 2. The reader is encouraged to study the inset at the bottom of the figure as it shows that there is a difference in the orientation of switch 2 and that of switches 11 and 12.

The new antenna is printed on a 0.79 mm thick FR4 substrate having a permittivity of 4.6, and a loss tangent of 0.018. The overall size of the antenna is 196 mm by 53 mm. Figs. 1 and 2 illustrate the geometry and the mechanism for reconfiguration. With switches 1 and 2 off and switches 3 to 12 on the wideband antenna operates in mode 1. Reversing the switch states (i.e., turning switches 1 and 2 on and 3 to 12 off) places the antenna in the second operating mode. Switches 3 to 6 are effectively connected in series, as are switches 7 to 10. This was necessary in order to achieve sufficient isolation when the switches were turned off. For the purpose of this proof-of-concept study on, and off microwave switches were represented by the presence or absence of copper metallisation, respectively. It is important to stress, once more, that reconfiguration of the antenna is entirely achieved by altering the configuration of the ground plane.

3. RESULTS

Figure 3 shows the reflection coefficient of the wideband antenna when it is operating in mode 1 (i.e., S_{11}), along side that of the narrowband slot antenna (i.e., S_{22}). The figure also depicts mutual coupling between the two antennas (S_{21}). A simple lumped element matching circuit was employed in order to increase the operating bandwidth of the wideband antenna.

The matching circuit consists of a series LC network, comprising a 6.2 pF capacitor, from AVX (series Accup, 0603 case style) along with a 5.6 nH inductor, from Coil Craft (series 0603HP). Under operating mode 1 the wideband antenna provides a 6.5 dB return loss bandwidth which ranges from 462 MHz to 1.51 GHz (106%). Over this frequency band the minimum values of gain and efficiency are 1.54 dB and 44.92%, respectively. This frequency range is more than sufficient to cover the DVH-B band (470 MHz to 702 MHz or 862 MHz), as well as any possible frequencies which are released for CR, UWB, or cellular use following the digital switchover. We chose to refer to the 6.5 dB return loss bandwidth because this is the best performance that can achieve across the band. This would be more than sufficient to meet the requirements of DVB-H. Fig. 4 shows the reflection coefficient of the wideband antenna when it is operating in mode 2 (i.e., S_{11}), along side that of the narrowband slot antenna (i.e., S_{22}). The figure also depicts mutual coupling between the two antennas (S_{21}). Under mode 2 the wideband antenna provides a 6.5 dB return loss bandwidth which extends from approximately 1.31 GHz to a frequency in excess of 12 GHz (see Fig. 4). Over this frequency band the minimum values of gain and efficiency are 1.69 dB and 58%, respectively.

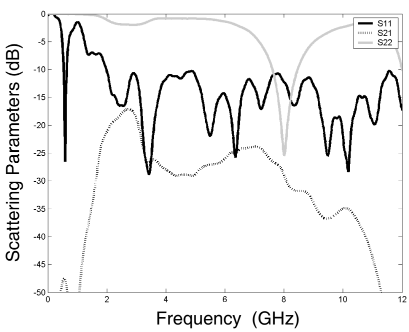


Figure 3. Scattering parameters for the antennas when operating in mode 1.

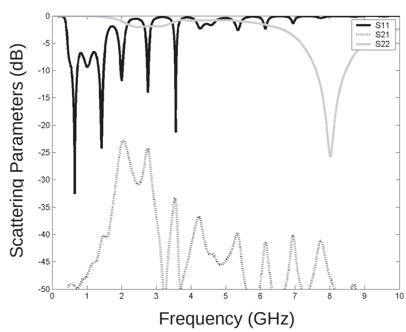


Figure 4. Scattering parameters for the antennas when operating in mode 2.

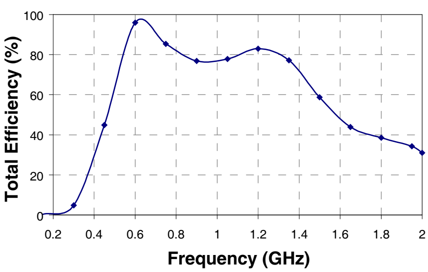


Figure 5. Total efficiency of the antennas when operating in mode 1.

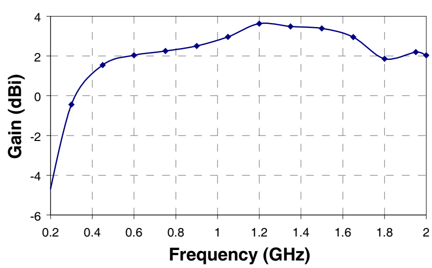


Figure 6. Gain of the antennas when operating in mode 1.

This is sufficient to cover the GPS (1575.42 MHz), GSM, PCS, DCS (850 MHz, 900 MHz, 1800 MHz, and 1900 MHz), Dect (1880 MHz to 1900 MHz in Europe), WLAN (5.725 GHz to 5.82 5 GHz), Bluetooth (2.4 GHz ISM band), and UWB (3.1 GHz to 10.6 GHz) bands. It also covers the UMTS frequency band. Together modes 1 and 2 cover the likely requirements of CR (i.e., 100 MHz to 2.5 GHz, 4 GHz, or 6 GHz). The antenna also yields a return loss of 10 dB, or better, throughout the majority of this band, and so the performance is more than sufficient to cover the requirements for operation within the FCC UWB band. When operating at frequencies between 1.31 GHz and 1.51 GHz one would select mode 2 (rather than mode 1) because it provides a slightly better return loss.

Figures 5 and 6 illustrate the total efficiency and gain of the wideband antenna when it is operating in mode 1. The minimum value of total efficiency is 65% at frequencies between 0.5 GHz and 1.45 GHz (see Fig. 5). From 0.6 GHz to 2 GHz the gain is fairly constant, ranging from 1.8 dBi to 3.6 dBi (see Fig. 5).

Figures 7 and 8 illustrate the total efficiency and gain of the wideband antenna when it is operating in mode 2. The total efficiency is greater than 58% from 1.35 GHz to 11.2 GHz (see Fig. 7). Over this frequency range the gain fluctuates from 2.3 dBi to 5.5 dBi (see Fig. 8).

Figure 9 shows radiation patterns for the wideband antenna when it is operating in mode 1. The E-plane patterns are figure-of-eight whilst the H-plane patterns are almost omni-directional. Figs. 10 and 11 show radiation patterns for the wideband antenna operating in mode 2. Both E-plane and H-plane patterns are fairly omni-directional.

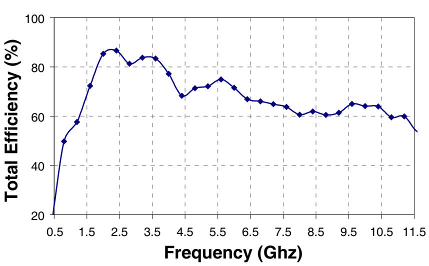


Figure 7. Total efficiency of the antennas when operating in mode 2.

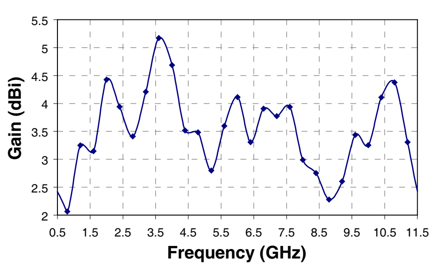
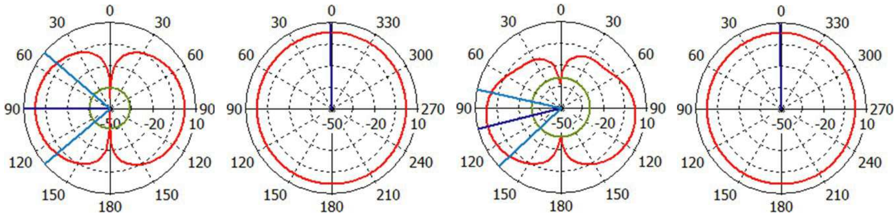
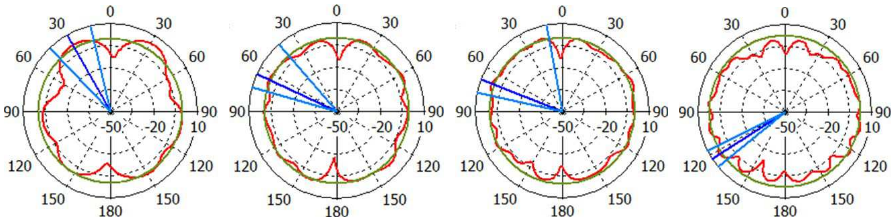


Figure 8. Gain of the antennas when operating in mode 2.



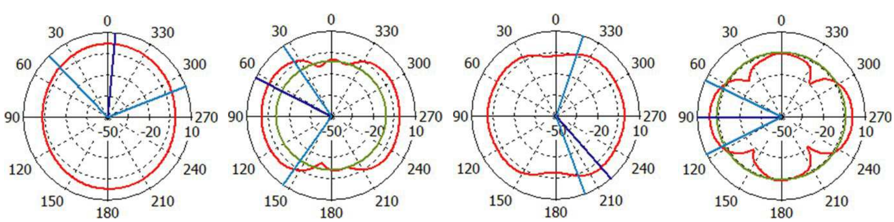
(a) (b) (c) (d)

Figure 9. Radiation patterns for the wideband antenna, operating in mode 1. Patterns were plotted at 0.612 GHz. (a) E-plane. (b) H-plane. Patterns were also plotted at 1.248 GHz. (c) E-plane. (d) H-plane.



(a) (b) (c) (d)

Figure 10. E-plane radiation patterns for the wideband antenna, operating in mode 2. Patterns were plotted at (a) 3.408 GHz, (b) 6.468 GHz, (c) 8.58 GHz, and (d) 10.284 GHz.



(a) (b) (c) (d)

Figure 11. H-plane radiation patterns for the wideband antenna, operating in mode 2. Patterns were plotted at (a) 3.408 GHz, (b) 6.468 GHz, (c) 8.58 GHz, and (d) 10.284 GHz.

4. CONCLUSION

Modern mobile phones enable their users to access a wide range of different entertainment, information, and data transfer services, including: Bluetooth, WLAN, GPS, and DVB-H. This presents a difficult challenge for the RF engineer who is already short of space in which to mount the antenna. Initially designers, faced with this problem, chose to employ several multiband antennas. This paper describes a more elegant and scalable solution to the problem. The new antenna can be reconfigured to operate efficiently over a 6.5 dB return loss bandwidth which ranges from 462 MHz to frequencies in excess of 12 GHz. The antenna does not provide coverage over the entire band simultaneously. However it can be reconfigured to operate over a low or high frequency operating band. The antenna is based around a cpw-fed monopole featuring an elliptical base. Reconfiguration is achieved using 12 microwave switches which effectively alter the shape of the ground plane between convex and concave. The use of a concave ground plane, improves the impedance match, at the feed point, throughout the low frequency band (i.e., below 1.51 GHz), whilst use of a convex ground plane improves the impedance match within the high frequency band (i.e., above 1.51 GHz). When the antenna is configured to operate in the low frequency band (mode 1) it provides a total efficiency in excess of 65% from 0.5 GHz to 1.51 GHz). When the antenna is configured to operate in the high frequency band (mode 2) the total efficiency is greater than 58% from 1.35 GHz to 11.2 GHz. A narrowband antenna has also been integrated into the ground plane for the wideband antenna. This enables it to address the requirements of future Cognitive Radio devices.

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