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Head and hand detuning effect study of narrow-band against wide-band mobile phone antennas

P. Bahramzy and G.F. Pedersen

Wide-band (WB) and narrow-band (NB) antennas in terms of performance are compared, when interacting with the user's right head and hand (RHH). The investigations are done through experimental measurements, using standardised head phantom and hand. It is shown that WB antennas detune more than NB antennas, but the drop in efficiency, when placed in RHH position, is similar for both antennas.

Introduction: The frequency spectrum for mobile communication has been widened, ranging from 700 to 3800 MHz [1], to support a wide range of wireless technologies and provide a high data rate. One way to cover this wide frequency spectrum is by applying a wide-band (WB) antenna that has multi-resonant matching [2]. Another way is to use a tunable narrow-band (NB) antenna and adjust it for the frequencies of interest [3].

A major constraint, for antenna designers, is the interaction with the user, as it absorbs power as well as detunes the antenna. The user hand detunes the resonance frequency [4], where the head further disturbs the antenna near fields and causes more degradation of the resonance characteristics. Hence, in this Letter it is investigated how robust the NB antenna is to user effects compared to the WB antenna.

Measurement setup: Two types of antennas are studied for this Letter: NB and WB antennas, see Fig. 1. The low band (LB) and high band (HB) WB antennas cover 700–960 and 1710–2170 MHz, respectively. The LB and HB NB antennas cover only a small fraction of a band.

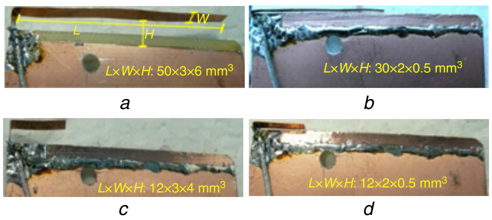

Fig. 1 *Antennas studied*

a LB WB antenna
b LB NB antenna
c HB WB antenna
d HB NB antenna

The single layer printed circuit board (PCB) together with the cover are shown in Fig. 2. Front and back covers ($\varepsilon_r = 2.8$) are designed and printed for enclosing the PCB, which allows for head and hand measurements.

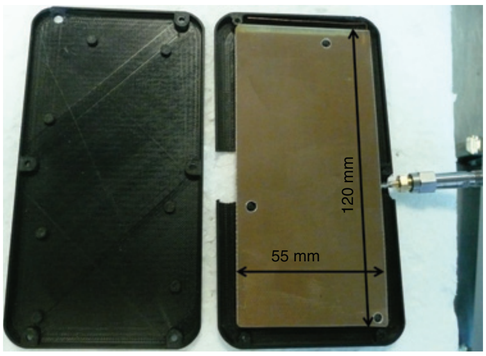

Fig. 2 *Mock-up consisting of PCB and antenna enclosed in plastic covers*

The NB antennas are matched using a series and a shunt inductor, whereas the WB antennas are matched using a series inductor, a shunt inductor and a shunt capacitor.

The head phantom and hand, used in this Letter, are standardised by the 3rd Generation Parternship Project (3GPP), specified in the Cellular Telecommunications Industry Association (CTIA) test plan and made by Speag. Fig. 3 shows the right hand (RH) and right head and hand (RHH) measurement setup. Fig. 3*a* shows the setup with the antenna located at the top of the PCB, where the bottom antenna placement is measured simply by rotating the mock-up by 180°. Only the right side is considered to limit the number of measurements.

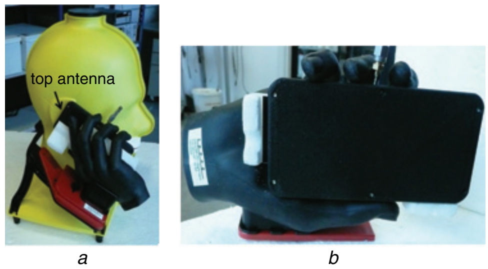

Fig. 3 *Measurement setup with standardised head and hand*

a RHH
b RH

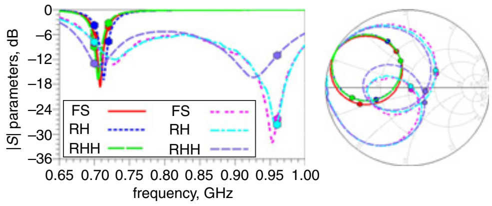

Fig. 4 *LB top antenna S-parameters and impedances*

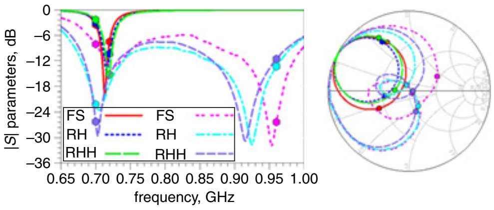

Fig. 5 *LB bottom antenna S-parameters and impedance*

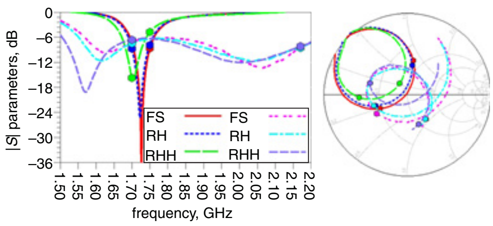

Fig. 6 *HB top antenna S-parameters and impedance*

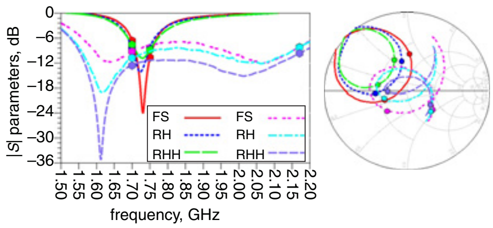

Fig. 7 *HB bottom antenna S-parameters and impedance*

Measurement results: The measured *S*-parameters and impedances of the LB and HB antennas are presented in Figs. 4–7. The Figures show free space (FS), RH and RHH measurements. The markers are set to: 700 and 720 MHz for LB NB case, 700 and 960 MHz for LB WB case, 1700 and 1750 MHz for HB NB case and 1700 and 2170 MHz for HB WB case. Detuning of the antennas (shift in frequency at standing wave ratio (SWR) = 3 compared to FS case) are listed in Table 1.

Table 1: Frequency detuning of NB and WB antennas compared to FS case

Config.	Use case	SWR = 3 point	Detuning (MHz)
LB NB top antenna	RH	low	4.5
		high	5.3
	RHH	low	2.8
		high	2.8
LB NB bottom antenna	RH	low	1.9
		high	3.4
	RHH	low	4.8
		high	5.9
HB NB top antenna	RH	low	4.4
		high	3.2
	RHH	low	22.8
		high	21.0
HB NB bottom antenna	RH	low	9.0
		high	6.6
	RHH	low	8.4
		high	3.6
LB WB top antenna	HR	low	0.4
		high	4.2
	RHH	low	16.2
		high	23.0
LB WB bottom antenna	RH	low	31.8
		high	14.8
	RHH	low	25.1
		high	16.6
HB WB top antenna	RH	low	16.7
		high	8.8
	RHH	low	63.1
		high	9.3
HB WB bottom antenna	RH	low	30.3
		high	1.8
	RHH	low	34.0
		high	31.1

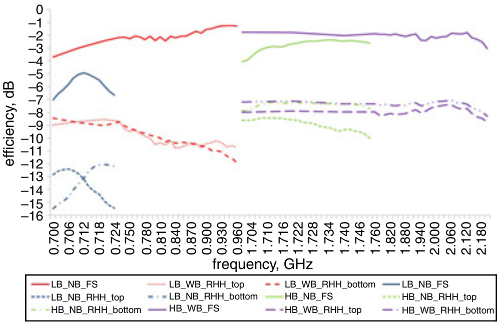

Fig. 8 *Measured total efficiency*

From the measurements, it can be observed that the NB antennas detune less compared to the WB antennas. A little detuning is not a big problem for WB antennas, since most frequency bands are still covered, and the small shift in frequency, due to the user or component tolerances, is typically taken into account in the antenna design phase. However, in the case of NB antennas, even a small detuning can be an issue since the antenna will be tuned outside the operating channel bandwidth. Owing to the tunable component, applied with the NB antenna, the detuning effect is not a severe problem, because the antenna can be tuned back. Antenna mismatch, on the other hand, is a bigger concern because the tunable component cannot solve the mismatch issue. Thus, additional tunable matching components will be necessary for matching the impedance in different user cases. However, based on the results in this Letter, mismatch seems not to be a significant problem.

From the efficiency graphs in Fig. 8, it is seen that efficiency of NB antennas drops more or less in the same degree as for WB antennas, when placed in the RHH position. This indicates that absorption losses (largest contributor to total antenna loss when placed in proximity of the user) of NB and WB antennas are similar. Mismatch loss (difference between radiation efficiency and total efficiency) for all cases is in the range 0.5–2 dB, and seems not to be notably different for the NB and WB antennas. It should be noted that NB antennas have lower efficiencies (specially at LB) compared to WB antennas due to their relatively high current densities.

Conclusion: In this Letter, the degradation of NB and WB antenna performance, placed in RH and RHH positions, has been investigated. It has been demonstrated through measurements that the drop in total efficiency of NB and WB antennas is comparable. However, NB antennas have lower efficiencies due to their relatively high current densities. NB antennas exhibit less detuning compared to WB antennas due to their more confined near fields. Yet even a small detuning can be a problem for NB antennas, as they will be tuned outside their operating channel bandwidth. However, the detuning issue can be solved by utilising tunable components with NB antennas. Mismatch is regarded as a bigger concern, as tunable components cannot solve it. However, the results show that mismatch is not a significant problem.

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One or more of the Figures in this Letter are available in colour online.

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