An Enhanced Multiple-Mode Penta-Band Antenna (EMMA) for Mobile Applications with Improved Beside Head and Hand Performance

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***Abstract*—A proposed Enhanced Multiple-Mode penta-band Antenna (EMMA) offers significant advantages over a conventional Planar Inverted-F Antenna (PIFA) and monopole antenna for a handheld device. EMMA antenna is characterized by a unique feed and ground placement and generated third mode in high-band. Due to the unique features, presented antenna has excellent use case performance, as in beside head and beside head and hand cases. The proposed antenna has been simulated, prototyped, tested, and implemented.**

I. INTRODUCTION

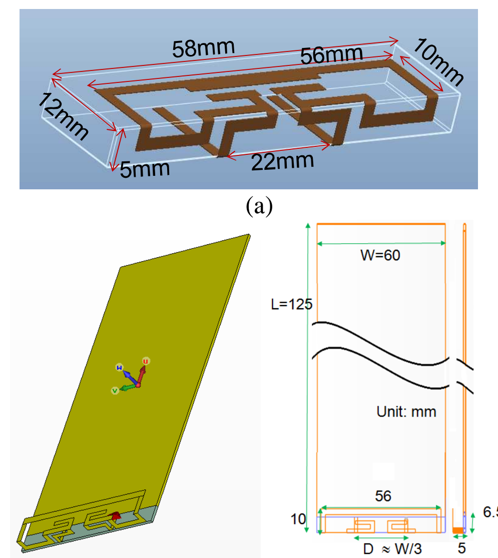
A significant interest on multiband loop antennas for mobile communication systems is been shown due to their unique multimode features [1]–[4]. Up to four resonant modes can be generated with a single loop antenna. A very attractive feature of the loop antenna is that it can operate as a folded monopole as well as a folded dipole, simultaneously. This enables a wideband operation, which is not achievable with other traditional antenna types, as PIFA, IFA, and monopole.

In the reference [1], four resonant modes have been explained. References [2]-[4] present different loop antenna designs, while some of them are printed structures. However, none of these references is paying any special attention or presenting many results on use cases in handheld devices, as beside head (BH) and beside head and hand (BHH).

In this paper, a novel internal Enhanced Multiple-Mode penta-band Antenna (EMMA) for mobile communications has been proposed. The proposed antenna has an important feature that it combines in a very efficient way loop and monopole structure. Based on a special radiator design, adjustment between the feed and ground terminal placement, and special optimization between the left and right BHH side, it provides a superior performance. Design principle, passive and active measurement results have been presented.

II. PROPOSED CONCEPT

The configuration of the proposed antenna (an Amphenol IPR) is illustrated in Fig. 1, where the radiator geometry without and with a ground plane is shown in Fig. 1(a) and (b), respectively. This antenna has a loop part for low-frequency response (low-band, LB) and a monopole part for high-frequency response (high-band, HB). Antenna is typically placed at the bottom of a mobile terminal, so called bottom mounted placement. In this case it is partially placed on top of ground plane with a size of 125 x 60 mm^2, which includes 6.5 x 60 mm^2 area under antenna in which ground is removed. A typical proposed antenna size is 56 x 10 x 5 mm^3, as shown in Fig. 1. Distance between feed and ground (D) is optimized as 22mm, which in general case is about W/3, where W is the width of the ground plane.



(a)

(b)

Figure 1. A proposed EMMA antenna.

Return loss of the presented EMMA antenna in free space (FS) is shown in Fig. 2. It has 4 resonances. Resonance frequency f0 in LB, as shown in Fig. 2 is a half-wavelength mode, which is mainly determined by the total length of the main loop. The current distribution of this resonance frequency is well known and it is not shown here. The resonance frequency f1 in HB is a full wavelength mode. Fig. 3(a) shows the corresponding current distribution for this mode, where F indicates feed point while G indicates ground. The dark arrows indicate currents on the antenna and grey arrows indicate currents on the ground near to antenna. This is a differential mode. The second resonance in HB, f2, represents a common mode, with the current distribution shown in Fig. 3(b). The third resonance frequency in HB, f3, represents a 2 mode and it is a unique differential mode with the current distribution shown in Fig. 3(c).

There are a few unique features of presented EMMA antenna. One of them is that the given radiator shapes with the monopole branches gives a good freedom to efficiently tune all resonant modes. Another one is the distance between the feed and ground terminal, D. This distance provides the possibility to balance the performance (typically efficiency) in the use cases, especially BHH case. This is very important as equal radiation for left and right side is preferred and required. Another advantage of having feed and ground spaced apart is that provided area is typically occupied by some mechanical components in the modern handsets, as for example USB connector.

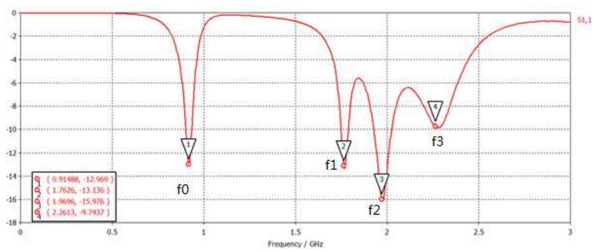
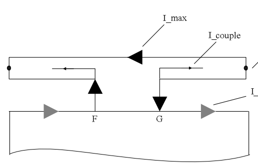
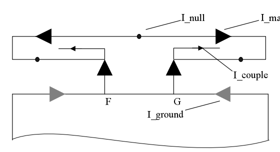


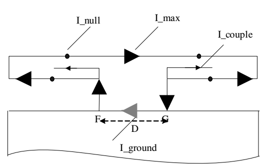
Figure 2. Reflection coefficient of proposed EMMA antenna.



(a)



(b)



(c)

Figure 3. Current distribution of proposed antenna.

A symmetrical structure of presented antenna, together with the above described features and current distributions, result in a very efficient antenna, which main characteristic is that it suffers lower absorption losses in use cases compared to the other known structures.

A. *Measured Efficiency*

Three antennas of the same size, as above explained EMMA antenna, have been designed, made and measured. They are covering typical penta-band operation, i.e. 850/900/1800/1900/2100 bands. Total (measured) efficiency is presented in Fig. 4. It is given for 2 cases, FS and BHH. It can be observed that proposed EMMA antenna outperforms the other ones in the most important use case, BHH.

B. *Active OTA Measurements*

The proposed EMMA antenna is been implemented in a commercial phone, active results measured (TRP and TIS) and compared to the original/reference penta-band antenna from the phone. While being better also in FS and BH, the main advantage of EMMA antenna is in BHH, and measured TRP results for GSM bands are illustrated in Fig. 5.

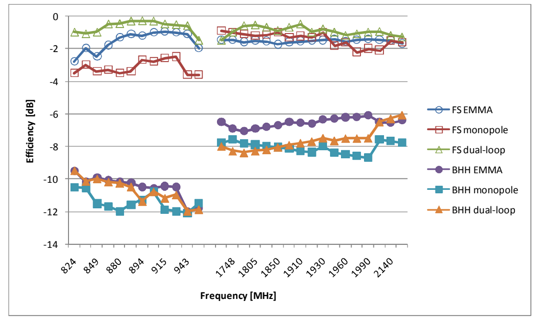


Figure 4. Total (measured) efficiency in FS and BHHR (right side).

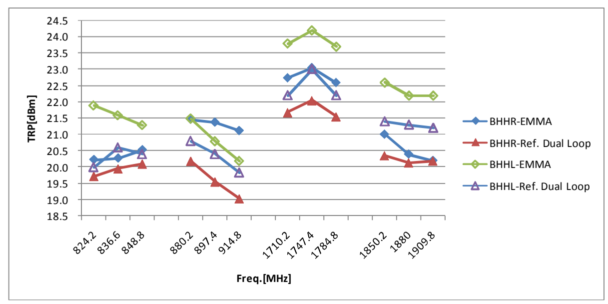


Figure 5. Measured TRP in BHH.

III. Conclusion

A novel EMMA antenna with four resonant modes has been demonstrated. This design allows mitigating end users' effects due to the close proximity between users' hands and heads and handheld devices with embedded antennas. Design principle, prototype measurements, and active implementation results have been presented, too. Better BHH performance compared to the traditional, reference antennas is the main advantage.

References

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