Adaptive Matching Circuitry for Compensation of Finger Effect on Handset Antennas

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ABSTRACT -In this paper we present and evaluate the effect of hand on terminal antenna and discuss a method to compensate for the mismatch. A dual band PIFA was used in this study. The presence of the hand was observed to cause 2-6dB loss in efficiency in low-band and 2-4dB loss in high-band. In this study we propose a dynamic antenna matching (DAM) technique to improve matching level that can improve the total efficiency of the antenna by 2 – 4dB compared to the mismatched case.

Keywords: Dynamic Antenna Match, Terminal Antenna, Total Efficiency, Mismatch.

I. INTRODUCTION

Today's mobile communication networks require highly efficient and reliable mobile terminal performance since its radio performance may reduce the coverage and/or the capacity of the whole network [1]. One of the key elements in determining the performance is the efficiency of antenna under various operating conditions. Another important aspect is the Power Added Efficiency (PAE) from the PA to the antenna (load). The antenna (load) is a radiating device, sensitive to the surrounding environment under which it is operated. Terminal antenna design is generally optimised for highest TRP in freespace condition. Currently in 3GPP, a hand is being standardised and performance level in the presence of hand with finger placed on the antenna for one position needs to be satisfied. This criteria takes into account the most common holding position of the terminal, but the operating surrounding can vary for every user based on his/her way of using the terminal. The conditions like besides head, held in hand, on dielectric / metal table vary the characteristics like impedance, resonant frequency, Q-values of the antenna in different ways, and hence the antenna doesn't give the same performance for which it is optimized. This impedance mismatch of the antenna causes losses, due increased reflected power, which the power amplifier (PA) tries to compensate for by increasing its output power [2]. This increase in output power then results not only in an increased level of harmonic spurious emissions from the PA, but also higher current consumption from the battery hence reducing the talk-time of the mobile terminal

The effect of presence of hand and head has been studied and presented in several articles [2-5]. The losses that are reported can be broadly divided into two parts:

- Absorptive Losses
- Losses due to mismatch

The absorptive losses are caused due to the absorption of radiation by hand and head tissues. Reduction of this type of losses is difficult owing to the dimension of these surrounding objects when compared to the device's antenna dimension. To address this issue, adaptive radiation pattern type of antenna solutions are studied [6], but are unrealistic due to the dimension limitations and since the absorption is caused due to near field interaction.

The losses due to mismatch, i.e reduced PAE, which governs the power from the PA to the antenna, occurs due to detuning of the antenna in frequency and impedance. Couple of different types of solutions based on MEMS, tunable capacitors, varactors have been reported [8-10]. But all these solutions suffer due to different problems like power handling capability, component life, reliability, harmonics etc.

Hence there is a void of a solution which is practical and can address the need of the extent of mismatch generally observed in the antenna. This paper intends to suggest a solution which can fill this void.

II. EFFECT OF PRESENCE OF HAND

The effect of presence of hand/head has been studied and presented in open literature [2-5]. It has been reported that the total losses are in the range of 14-18dB for PIFA type of antenna at the low band (GSM 850/900) and close to 19dB for monopole type antennas. At high band(GSM 1800/1900) the total losses can be about 6-14dB for PIFA and up to 20dB for monopole. The mismatch losses are reported to be 0-4dB for low band and 0-3dB for high band. However, these losses depend heavily on the antenna design and the position of finger. To study the effect of only the hand, a dual band PIFA [7] of dimension (42mm x 16mm x 7mm) was made, as in Fig.1.

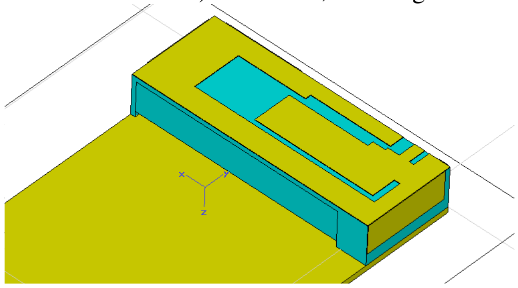

Fig. 1 Dual Band PIFA prototype

Fig. 2 PIFA prototype in freespace and in hand

The antenna in freespace and in hand as used in this study is shown in Fig. 2. In the presence of hand/head, the antenna sees an external loading capacitance. This causes a shift in resonant frequency and an impedance change of the antenna. The antenna thus goes far away from the -6dB matching criteria (at band edges) for which it has been designed. From the efficiency graphs, as in Fig. 5, it can be observed that that the losses, due to the presence of the hand, are about 2-6dB for low-band and 2-4dB for high band performance. To reduce the loss caused due to this mismatch, the antenna has to be re-matched close to 50-ohm.

To cover most of the mismatch conditions on the smith chart, "L" type of matching network of different topologies is sufficient. This type of network can be utilised to get a good enough matching criterion for the entire operating band. The number of combinations required to match each frequency point ideally back to 50 ohm for different mismatch conditions is very high. But for practical purposes, the number of topologies of matching network required is not too high. A configuration of "T" or "Π" network comprises of two "L" type of networks at a time, which can be used effectively for compensating mismatch of the antenna.

The matching circuit can be implemented using different types of approaches, like varactors [9], BST varactors, PIN diode based switching [10] or MEMS switches [8]. The traditional varactors cannot handle high power levels whereas BST varactors require high operating voltage and have low tuning ratio. PIN diodes require high current (in order of few mA) for proper operation and MEMS switches suffer from production issues and large bias voltage requirements.

In this study, a GaAS technology based semiconductor switch (SP4T) has been used. The switch operates on 2.7V bias and consumes very less current, in the order of μA.

III. Design Process

The antenna used is a traditional dual band PIFA as mentioned earlier. At the feed the dynamic antenna matching circuit is introduced and the radiator is optimized along with the circuit for the freespace operating condition.

The "Π" type network topology is used since the introduction of switches in series in a highly non-50ohm scenario gives rise to reflection losses. The usage of series element switching is avoided, since these switches are designed for 50 ohm and the antenna shows a huge mismatch. This would hence cause large reflection loss apart from insertion loss of the switch. Thus as a compromise a fixed series component using switches on the two shunt branches is utilised. The series component is chosen in such a way that it can move the impedance of the low-band and the high-band detuned cases effectively, such that the shunt branches can re-match the antenna. For the free space scenario, the switches are placed in a state where it offers "open" state i.e. very high impedance. To achieve this open state, separate stages of the switch were used for low band and high band respectively.

The antenna design is as shown in Fig. 1. Antenna s-parameter in the detune case were recorded for different finger positions, where the finger shows strong effect to the respective bands. This data is then used to model the matching circuit using Microwave Office™. Two port s-parameter data block of the switch was used in the simulation to simulate and identify the required matching components. This is followed by the implementation of antenna along with the Dynamic Antenna Matching (DAM) circuit as shown in Fig. 3.

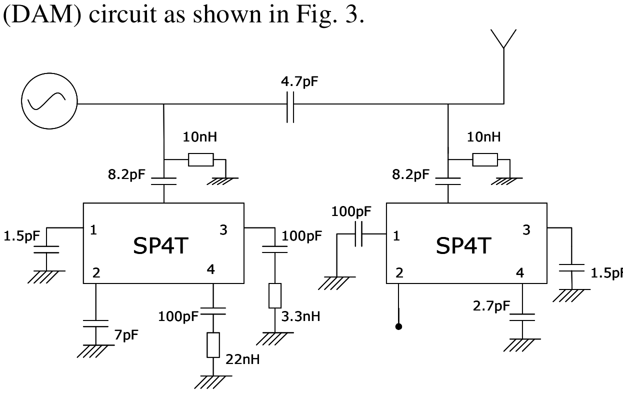

Fig. 3. Dynamic Antenna Matching (DAM)

Depending on the operating condition and band, the switch states needs to be selected as given in Table 1.

TABLE 1 SWITCH STATES FOR DAM CIRCUITRY

Operating Band	Operating State	DAM Circuit Switch	
		Switch 1	Switch 2
850	Freespace	State 3	State 3
	in Hand	State 4	State 2
1800	Freespace	State 1	State 3
	in Hand	State 3	State 4

The return loss and impedance state in smith chart can be observed from Fig. 4(a, b) for low-band operation and Fig. 4(c, d) for high-band operation.

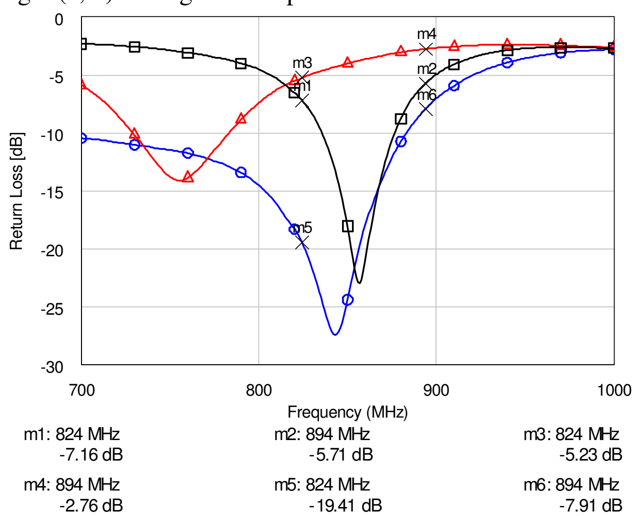

Fig. 4a. Low Band – Return Loss

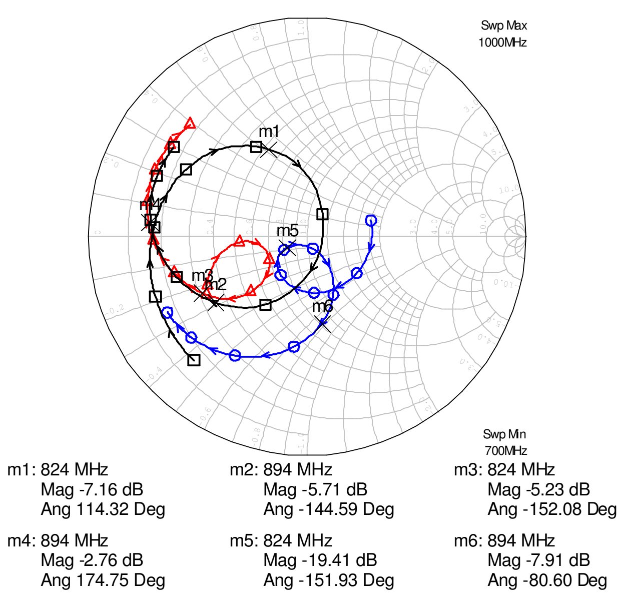

Fig. 4b. Low Band – Smith Chart

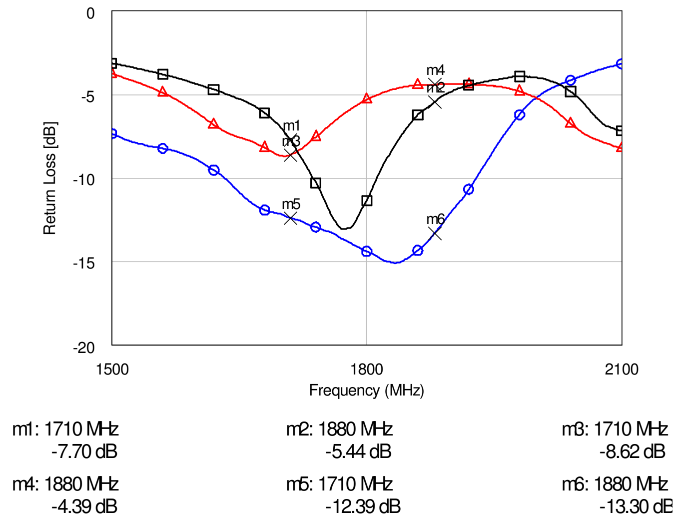

Fig. 4c. High Band – Return Loss

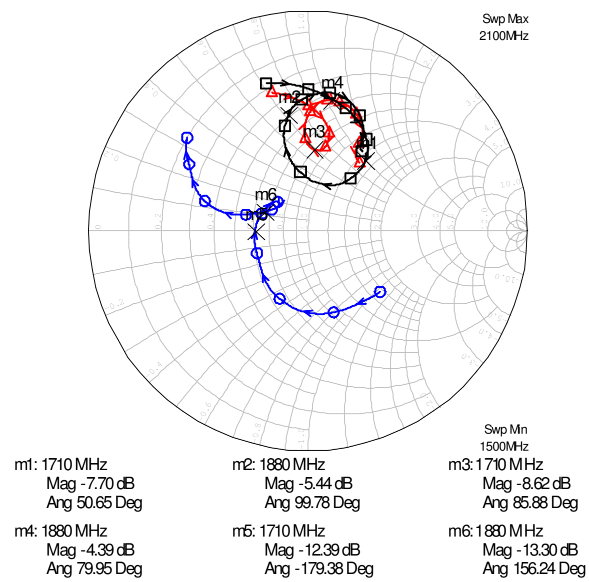

Fig. 4d. High Band – Smith Chart

Antenna in Freespace
Antenna detuned due to Hand
Antenna in Hand with compensated state

The total efficiency of the antenna measured in Satimo Stargate64 chamber in freespace and in hand is as given below in Fig. 5. From the plots we can observe that the compensation in mismatch caused due to hand, gives an improvement of 2-4dB for low-band and 1.5- 2dB for the high-band.

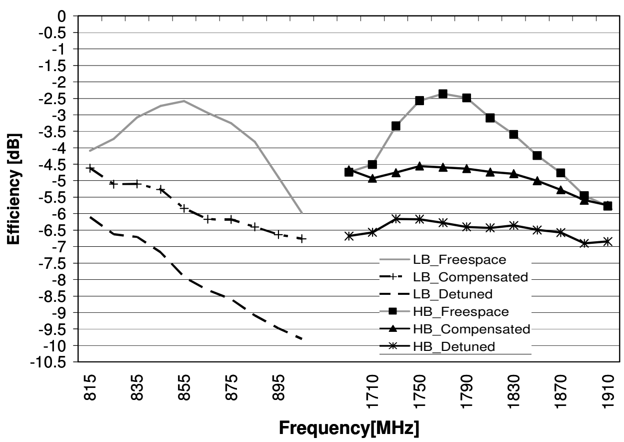

Fig. 5. Compensation of antenna mismatch using Dynamic Antenna Matching

Mobile phones in general continuously monitor the VSWR on the feed line to the antenna. Thus the information regarding the mismatch can be obtained from the same VSWR monitor and can be further used by the baseband processor to control the switches adaptively using simple DC control lines or through message word, depending on the method suitable for the switch.

IV. Discussion and Conclusions

In this study a traditional dual band PIFA antenna has been used to study the effect of hand causing worst case detuning and its effect on the impedance mismatch. A novel and very efficient method to compensate for the impedance mismatch of the antenna has been proposed. It is based on a simple DAM tuning circuitry, which introduces very small insertion loss. This compensation in impedance gives an improvement in performance of 2-4dB for the low-band and 2dB for the high-band. This gives a great benefit for in terms of lower power consumption, longer battery life.

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