Dual Frequency Inverted-S Antenna for Mobile Handset Devices

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A novel dual frequency band inverted-S antenna (ISA) using low profile PCB configuration developed for mobile handset devices in wireless communications is presented. The ISA consists of two radiating elements mounted on a small rectangular PCB with one folded element connected to the ground line and the others directly connected to the source. Two resonant frequencies are obtained at 900 MHz and 1800 MHz with the bandwidths over 7 % and 10 % at −10 dB for the ISA respectively. The directional ISA (D-ISA) with dual frequency bands is also presented. The front and back ratios of D-ISA are 10 dB and 7 dB at 925 MHz and 1790 MHz respectively.

Key Words: Dual frequency band, Inverted-S antenna (ISA), IFA, Mobile handset devices.

1. Introduction

A microstrip antenna with a centrally located feed element between a folded and parasitic element to form a directional antenna was originally developed in the early 1990's and patented in Australia [1] and USA [2]. Based on the configuration of this directional antenna, it was found that the folded element connected to the ground line and the central element connected to the feed can produce an adjustable dual frequency and provide omnidirectional radiation patterns at the two frequency bands. In contrast to inverted-F antennas (IFA) [3]-[4], this antenna is named an inverted-S antenna (ISA) which can be used in mobile handset devices due to its physically small size and dual frequency band characteristics. Since many mobile wireless communications systems operate over two or more frequency bands, mobile antennas that operate in more than one frequency band are required. Preferably these antennas can operate at the two or three frequencies simultaneously with similar radiation patterns. This paper introduces a dual frequency band ISA and the original directional ISA dual frequency antenna, and reports their measured characteristics at dual frequencies. This low profile dual frequency band antenna can be used for mobile communications and wireless computing.

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2. The Configuration of the Inverted-S Antenna

The basic ISA consists of two separate radiation elements as shown in Fig. 1. Element 1 is a folded element mounted on the PCB connected to ground of the coaxial feed. Element 3 is parallel mounted on the same side of PCB and is directly connected to the feed. To increase antenna performance at dual frequencies, an additional element 2 is attached to element 3.

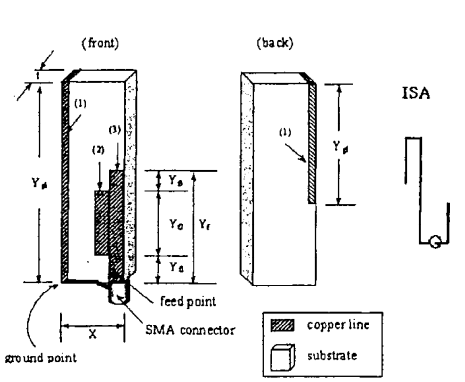


Fig. 1. Configuration of ISA

Unlike planar IFA antennas and small dual frequency microstrip antennas [5], the ISA does not require a ground plane, and it can be directly connected to a coaxial feed as an external antenna or directly built on the PCB as a built-in antenna configuration. This frequency adjustable ISA can be used for many frequency ranges in mobile communications systems and wireless computing, such as the IEEE 802 series at 2.4 GHz and 5 GHz.

3. Inverted-S Antenna Design

3.1 The basic concept

The dual frequency antenna is based on two ¼ wavelength monopole antennas, where each element length corresponds to a different frequency band. In Fig. 1, element 1 connected to ground was found to determine the position of the resonant frequency f_1 aimed for GSM900 applications. The feed element 3 was found to determine the resonant frequency f_2 aimed for DCS1800 applications.

It was found that the return loss S_{11} for f_2 was significantly affected by the length of element 3. Based on these observations, the design was optimized. Compared to two monopole elements based dual frequency antenna, the ISA has achieved a significant improvement in dual frequency band performance with many advantages, including small size, relatively wide frequency bandwidth, and adjustable frequency range [6]. The design was refined because: (a) narrowing the ground line made the frequency bandwidth for GSM900 wider, (b) adding a small piece of line (element 2) next to the feed line and moving the position improved the return loss, S_{11} with a change in resonant frequency f_2. The antenna was optimized by varying the lengths of all elements and their positions to produce a dual frequency band antenna.

3.2 Measurement results of dual frequency ISA

The ISA testing was carried out with a mobile handset chassis. Fig. 2 shows the experiment configuration of the ISA, where the ISA was positioned on the top of the chassis. Fig. 3 illustrates the measured radiation patterns with the chassis at two different frequency bands respectively. The radiation patterns are similar to omnidirection patterns at both frequencies, and the chassis of the mobile handset device did not have a strong impact on the radiation pattern.

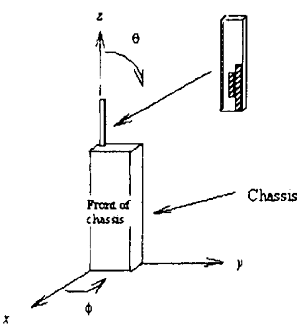


Fig. 2. The configuration of ISA with chassis

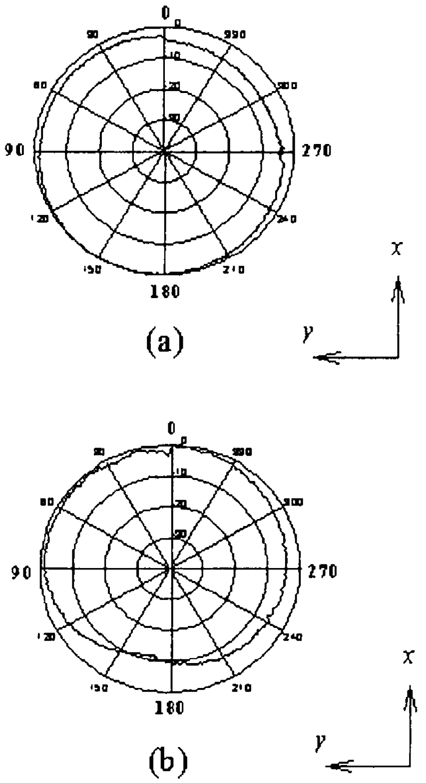


Fig. 3. Measured radiation patterns with chassis,
(a) at operating frequency, 900 MHz,
(b) at operating frequency, 1800 MHz

The measured return loss plot shown in Fig. 4 indicated that the frequency bandwidth at −10 dB is around 70 MHz at f_1 and 200 MHz at f_2 respectively.

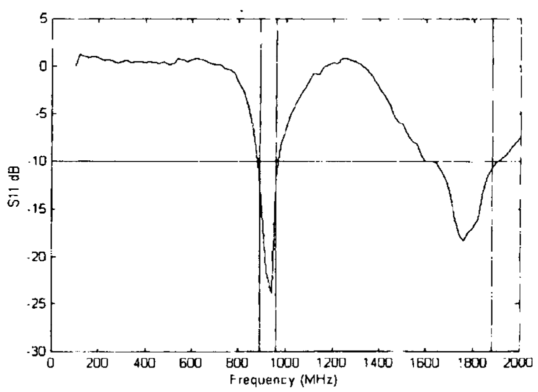
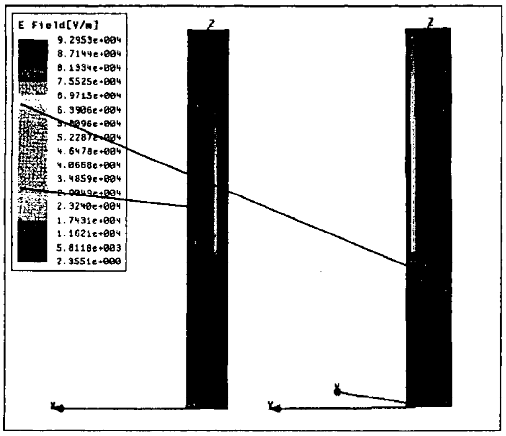


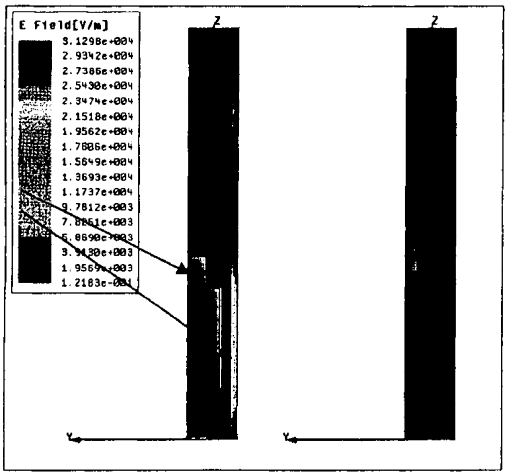
Fig. 4. The 50 Ω return loss of dual frequency ISA

3.4 FEM based simulation results of ISA

Simulation results based on a frequency domain FEM software package, High Frequency Structure Simulator (HFSS) [7] are shown in Fig. 5. The simulation results show the electric field distribution in the ISA at both frequencies. It can be seen that the majority of the field strength is concentrated at the end of element 1 which is acting as a main radiating element at 900 MHz. However, the distribution of electric field strength is quite different with the frequency at 1800 MHz, where a strong electric field was found at the top end of element 2 and element 3, and coupled with element 1. Obviously, there was a significant field coupling between elements 2-3 and element 1.



(a) Operating frequency at 900MHz



(b) Operating frequency at 1800MHz

Fig. 5. E-field strength and distribution on the ISA at 900 MHz and 1800 MHz

4. Directional ISA for Mobile Handset Devices

4.1 Configuration of Directional ISA

Fig. 6 shows a configuration of the directional ISA (D-ISA), which is a combination of the ISA and an additional element used as a director. The director of the D-ISA is pointed to the opposite direction of human body. By using such a D-ISA, the maximum specific absorption rate (SAR) for a human operated handset can be reduced.

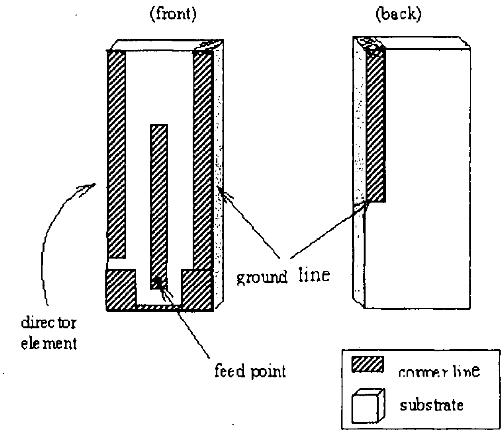


Fig. 6. Configuration of dual frequency D-ISA

4.2 Measurement results with chassis

The return loss of the D-ISA shown in Fig. 7 indicates that the dual frequency band at each desired frequency range has a reasonably wide impedance bandwidth at −10 dB. The bandwidth is around 10 % at f_1 and 6 % at f_2 respectively. The bandwidth of f_2 could be improved further by using an additional element to attach to the central driven element.

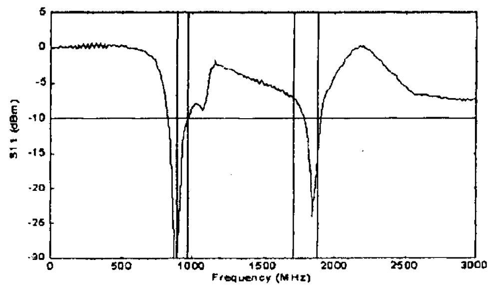


Fig. 7. Return loss of dual frequency D-ISA

Table 1 lists the front to back ratio of the radiation pattern for the D-ISA with chassis. Case (1) through (4) represent 4 different pointing directions of the D-ISA. The best performance is Case (1), which points to the opposite direction of the user, and the worse case is Case (2), which points to the user.

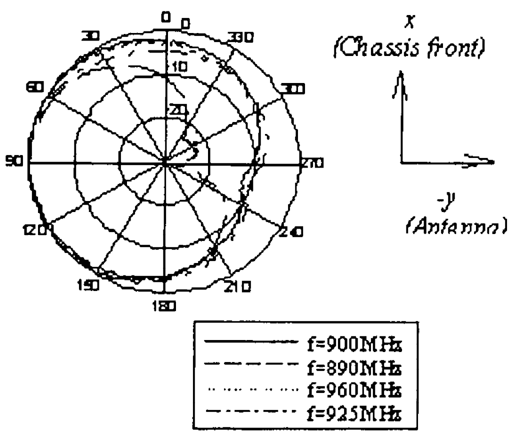
Table 1. Front-to-Back ratio of radiation pattern

Antenna with chassis	f_1=925MHz	f_2=1795MHz
Case (1)	10dB	7dB
Case (2)	4dB	5dB
Case (3)	4dB	8dB
Case (4)	7dB	4dB

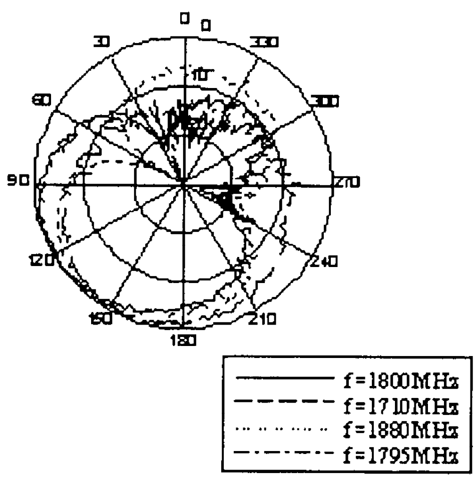
Fig. 8 shows the radiation patterns for both operating frequencies at Case (1). It was found that the maximum radiation is in the direction of the director. This is a significant difference between the radiation patterns at f_1 and f_2.

5. Conclusion

A novel dual frequency band ISA has been developed. It provides a similar coverage in the azimuth plane for two different frequencies. This dual frequency band ISA concept can be applied to any other frequency band with similar configuration and frequency tuning techniques. The radiation pattern of the ISA is very uniform which means it would provide good coverage. The original version of the D-ISA has presented a unique radiation pattern which could reduce the maximum specific absorption rate.



(a)



(b)

Fig. 8. Radiation pattern of dual frequency D-ISA for Case (1), (a) at operating frequency, f_1, and (b) at operating frequency, f_2

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