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A Novel Wide-Band Planar Antenna for Multi-Standard Mobile Handsets

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Abstract – A novel wide-band planar antenna for multi-standard mobile handsets is proposed and analyzed in this paper. Operating in a wide-band (890-4100 MHz) with voltage standing wave ratio (VSWR) lower than 2:1, it covers most of the communications systems: Global System for Mobile Communication (GSM), Global Positioning System (GPS), Digital Communication System (DCS), Personal Communication System (PCS), Universal Mobile Telecommunication System (UMTS), Wireless Local Area Network (WLAN), Worldwide Interoperability for Microwave Access (WIMAX), etc. Having a small size (40 x 50mm) it can be mounted inside a mobile handset.

Keywords: antenna, wide-band, mobile handset

I. INTRODUCTION

Present and future wireless communications systems have high demands regarding the capabilities of the antennas that are mounted inside mobile handsets. Most of these existing systems already have the possibility to operate in two or more frequency bands.

Also the continuous development of wireless equipment led to the possibility of integrating various mobile terminals such as phones, GPS receivers and laptops, into a single device. All these terminals operate in different frequency bands so the possibility to produce and use a single wide-band antenna mounted inside that integrated device is very attractive.

Offering to the device's user, the possibility to access local communication systems in a worldwide roaming scenario, also must be considered, so most of the communication systems that operate in different frequency bands such as GSM (890-960 MHz), GPS (1559-1610 MHz), DCS (1710-1880 MHz), PCS (1850-1990 MHz), UMTS (1920-2170 MHz), WLAN (2400-2484 MHz) and WIMAX (3400-3600 MHz), will have to be covered.

A wide-band antenna will also offer a considerable advantage, the flexibility to accommodate future communication systems due to its continuous operating band.

Most of the modern mobile terminals are compact and have a small size. Their antennas are mounted inside to be protected against possible damages so physical limitations are imputed, such as lightweight and small occupied space.

Although in the past years, many papers [1]-[13] related to wide-band or multi-band antennas, were published, none of the proposed solutions are capable to cover the entire frequency domain for mobile communication.

In this paper, a novel wide-band planar antenna is proposed and analyzed. Operating in a wide-band from 890 MHz to 4100 MHz, with VSWR lower than 2:1, it covers most of the communications systems such as GSM, GPS, DCS, PCS, UMTS, WLAN, WIMAX, etc. Due to its small size of only 40 x 50 mm and also by adopting a printed planar structure it can be mounted inside a mobile handset.

The analysis of the proposed antenna is conducted by means of the full-wave method of moment with the support of a commercial software package called "Sonnet".

II. ANTENNA CONFIGURATION AND GEOMETRICAL PARAMETERS

The geometry of the proposed antenna is designed and shown in Fig. 1.

The planar antenna is printed on a substrate with the thickness of 0.4 mm and the relative dielectric constant $\varepsilon_r = 4.4$. Both sides of the substrate will be covered in cooper with the proposed thickness of 0.02 mm.

The antenna geometry consists of: a rectangular patch (length "Ld" 30 mm and width "Wd" 50 mm), a fork bridge (length "B" 10 mm, width 50 mm, distance between the two lateral arms "D" 35 mm and width of the middle arm "E" 1.5 mm) and two symmetrical rectangular slots (length "G" 4 mm, width "F" 20 mm, distance to upper edge "H" 2 mm and distance to left edge "I" 2 mm).

A 50 Ω microstrip line (length "L" 60 mm and width "W" 0.74 mm) is used to feed the proposed antenna, and is printed on the same side of substrate as the proposed antenna. On the other side of the substrate, there is a ground plane (length "Lm" 60 mm and width "Wm" 50 mm) below the microstrip feed

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line whose size is approximately equal to that of a typical handset ground plane.

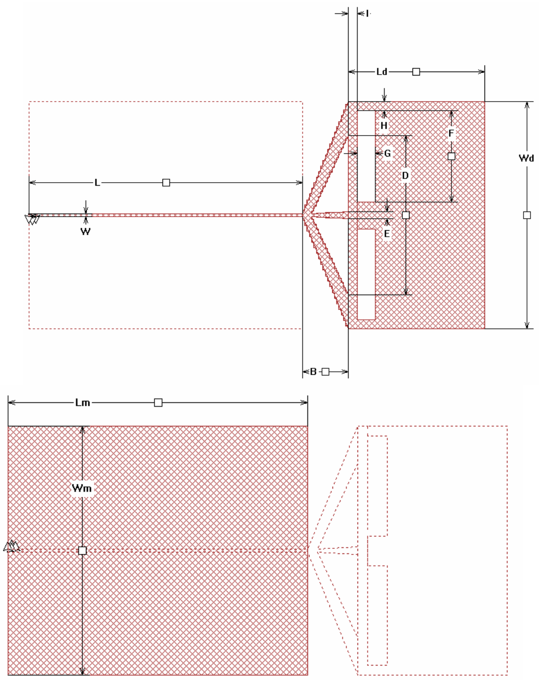

Fig. 1 Antenna's geometry with associated parameters. The dashed lines express the outline of the corresponding structure on the other side of the substrate.

III. DESIGNING STEPS AND EFFECTS OF THE GEOMETRICAL PARAMETERS

A. *Designing the rectangular patch*

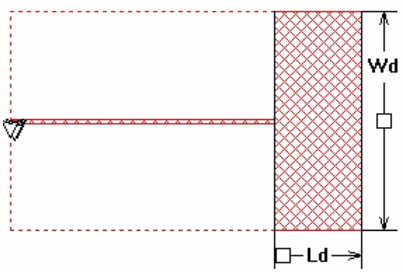

Fig. 2 Antenna's geometry with associated parameters for current design step.

The main radiating element will be the rectangular patch and in order to choose the correct values for its dimensions the patch was analyzed without the fork bridge and the two symmetrical slots. The effect of different dimensions for its length and width regarding the resonance frequency was empirically investigated. The following values were chosen in order to obtain the lowest possible value for the resonance frequency using limited size dimensions:

Ld = 20 mm and Wd = 50 mm.

Such a structure configuration (microstrip line connected directly to the rectangular patch) has big matching issues which are reflected in the obtained values for the real part of the input impedance of the rectangular patch over the analyzed frequency band as shown in Fig. 3.

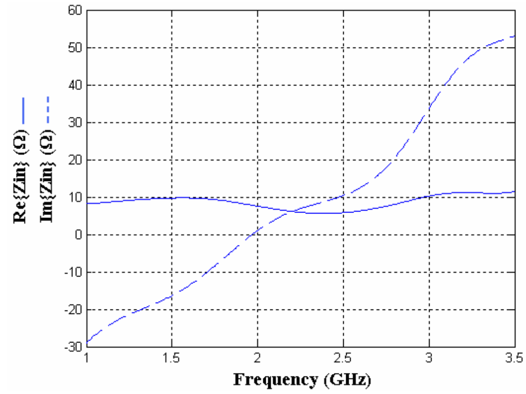

Fig. 3 Real and Imaginary part for the input impedance of the rectangular patch with dimensions of Ld=20 mm and Wd=50 mm

B. *Drifting away the rectangular patch from the ground plan. Adding a rectangular bridge*

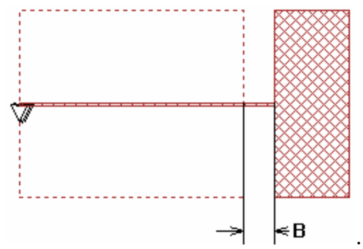

Fig. 4 Antenna's geometry with associated parameters for current design step.

The objective of this design step is to achieve a better matching between the microstrip line and the new compound structure (rectangular bridge and rectangular patch) and also to obtain an operating frequency band in the lower part of the mobile communication frequency domain. The structure from the previous design step is used. The rectangular patch is drifted away from the ground plane and a rectangular bridge with width of 0.74 mm and different length (parameter "B") dimension is added between the microstrip line and the rectangular patch.

Doing this, the capacitive effect that appears between the edge of the rectangular patch and the ground plane will reduce [1] and the real part of the input impedance of the new compound structure (rectangular bridge and rectangular patch) will increase as shown in Fig. 5.

The effect of different dimensions for the "B" parameter regarding the operating bandwidth was empirically investigated and is shown in Fig. 6.

The B=8 mm value is chosen due to the fact that the lowest operating band limit corresponds to the overall paper objective. The operating bandwidth is 0.68 GHz from 0.89 GHz to 1.57 GHz.

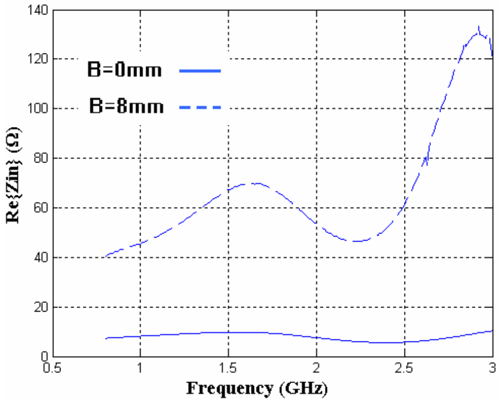

Fig. 5 Real part for the input impedance of the composed structure

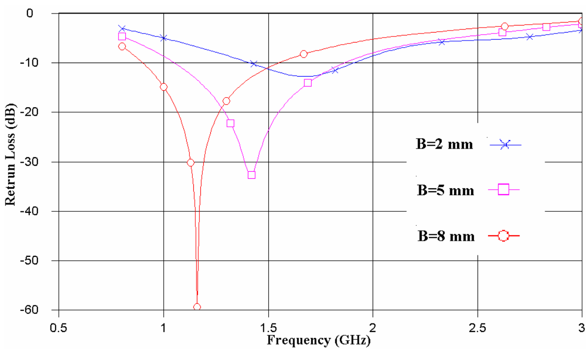

Fig. 6 Return Loss for B={2 mm, 5 mm, 8 mm}

C. Modifying the rectangular bridge into a trapezoidal shape bridge.

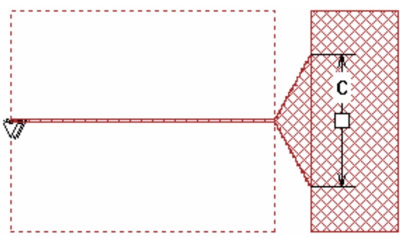

Fig. 7 Antenna's geometry with associated parameters for current design step.

The objective of this design step is to improve the matching between the microstrip line and the new compound structure (trapezoidal bridge and rectangular patch). The structure from the previous design step is used. The rectangular bridge is modified into a trapezoidal shape. The paper proposes an isosceles trapeze rotated with 90˚ with a height of 8 mm, small side of 0.74 mm and large side (parameter "C") of different dimensions.

The transition between the small width of the microstrip line and the large width of the rectangular patch will no longer be done suddenly but gradually over a length of 8 mm.

The effect of different dimensions for the "C" parameter regarding the real part of the input impedance of new compound structure (trapezoidal bridge and rectangular patch) was empirically investigated.

The C=50 mm value is chosen and its effect is shown in Fig. 8. The values for the real part decrease. This decrease is weaker for frequencies located in the lower part of the analyzed band and much stronger for frequencies located in the upper part.

Fig. 9 shows how the operating band changes if the "C" parameter takes different values. For C=50 mm the operating bandwidth is 1.74 GHz from 1.36 GHz to 3.1 GHz.

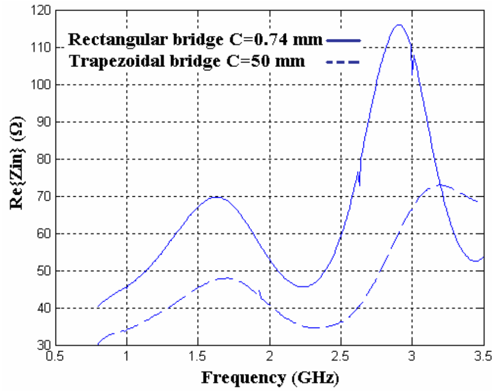

Fig. 8 Real part for the input impedance of the composed structure (trapezoidal bridge and rectangular patch)

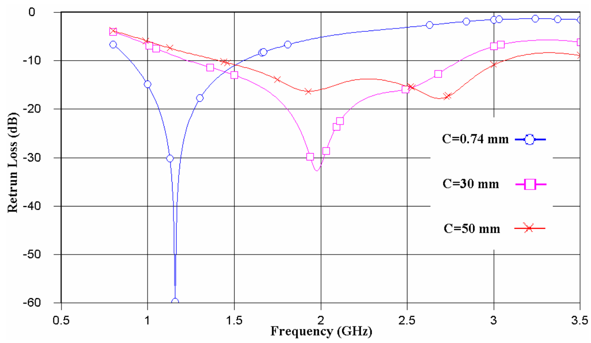

Fig. 9 Return Loss for C={0.74 mm, 30 mm, 50 mm}

D. Modifying the trapezoidal bridge into a fork shape bridge.

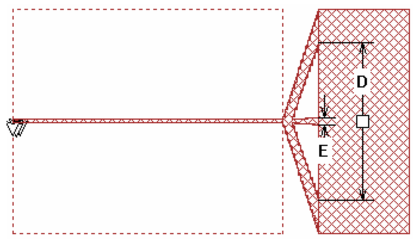

Fig. 10 Antenna's geometry with associated parameters for current design step.

The objective of this design step is to shift the operating band towards low frequencies. In order to do this the structure from the previous design step is used alongside two symmetrical slots that are created inside the trapezoidal bridge. Most of the current density is contained on the trapeze's edges so creating slots inside the trapeze will not have major effects on the improved matching obtained in the previous design step.

The new fork shape bridge is defined by the "D" and "E" parameters for which the following values are

empirically chosen due to the fact that the biggest translation towards low frequencies is obtained:
D=35 mm and E=1.5 mm

Fig. 11 shows how the operating band changes. With the fork bridge, the operating bandwidth is 1.69 GHz from 1.26 GHz to 2.95 GHz.

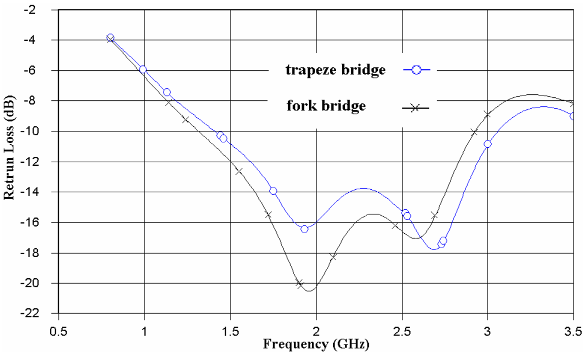

Fig. 11 Return Loss for the two bridge shapes

E. *Enlarging the length of the rectangular patch*

The objective of this design step is to enlarge the operating bandwidth.

The structure from the previous design step is used and the effect of different dimensions for the rectangular patch's length "Ld" regarding the operating bandwidth was empirically investigate and is shown in Fig. 12.

The Ld=30 mm value is chosen due to the fact that the largest bandwidth is obtained. For Ld=30 mm, the operating bandwidth is 2.37 GHz from 1.02 GHz to 3.39 GHz.

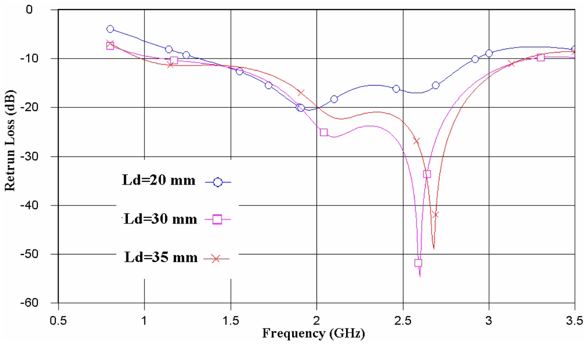

Fig. 12 Return Loss for Ld={20 mm, 30 mm, 35 mm}

F. *Creating two symmetrical rectangular slots inside the rectangular patch*

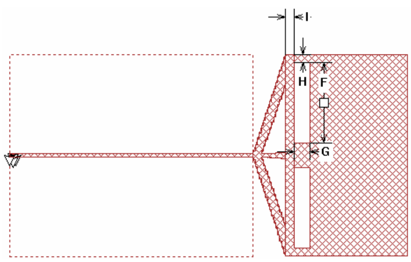

Fig. 13 Antenna's geometry with associated parameters for current design step.

The objective of this design step is to enlarge the operating bandwidth towards upper frequencies. In order to do this the structure from the previous design step is used alongside two symmetrical rectangular slots that are created inside the rectangular patch. Both slots are defined by the following parameters: length "G", width "F", distance to upper edge "H" and distance to left edge "I".

The operating bandwidth will be enlarged towards upper frequencies due to the fact that a multi-resonance structure will be obtained.

The effect of different dimensions for the "G", "F", "H" and "I" parameters regarding the operating bandwidth was empirically investigated and the following values were chosen due to the fact that the largest bandwidth is obtained:
G=4 mm, F=20 mm, H=2 mm and I=2 mm

The effect of the two slots, defined by the previous mentioned values, is shown in Fig. 14. The new operating bandwidth is 3.17 GHz from 0.96 GHz to 4.13 GHz.

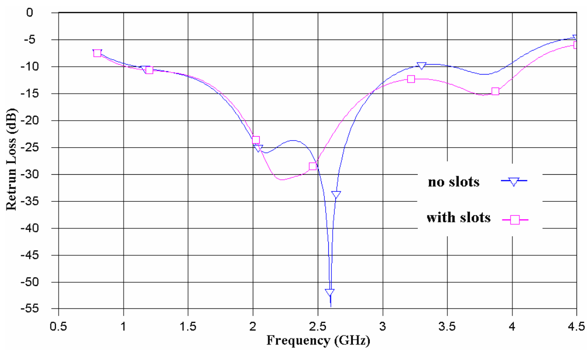

Fig. 14 Return Loss for the configuration without or with two

G. *Enlarging the length of the fork bridge*

The objective of this design step is to enlarge the operating bandwidth towards lower frequencies and to achieve the overall proposed bandwidth. In order to do this, the structure from the previous design step is used and the fork's length ("B" parameter) is enlarged from 8 mm to 10 mm. The enlargement effect is shown in Fig. 15. The new operating bandwidth is 3.21 GHz from 0.89 GHz to 4.1 GHz.

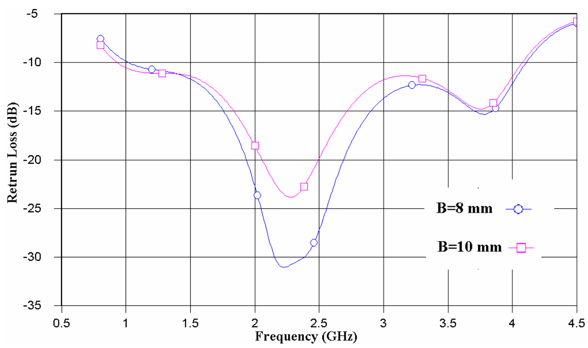

Fig. 15 Return Loss for B={8 mm , 10 mm}

IV. ANTENNA CHARACTERISTICS

The proposed antenna operates in a wide-band from 890 MHz to 4100 MHz, with VSWR lower than 2:1 as shown in Fig. 15.

Gain characteristics are displayed in Fig. 16-20.

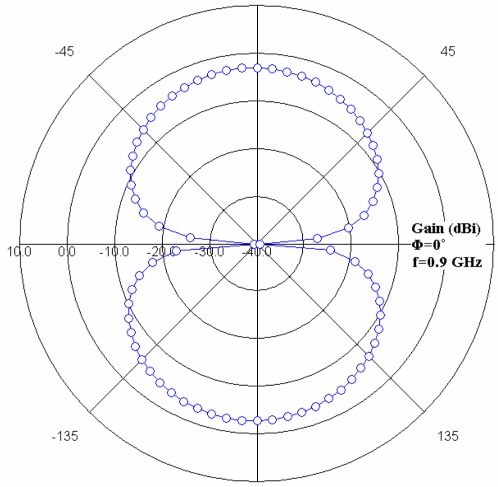

Fig. 16 Antenna’s gain (dBi) in the elevation plane for Φ=0˚ and frequency 0.9 GHz

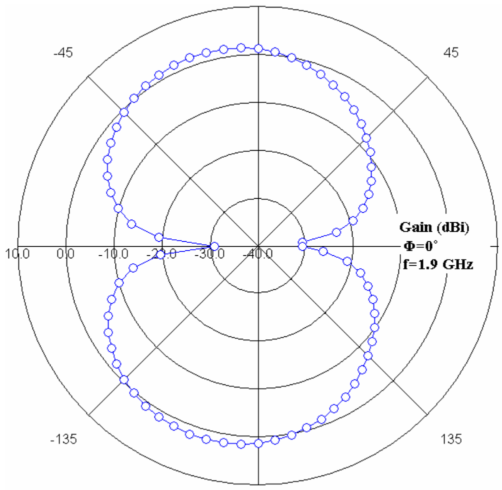

Fig. 17 Antenna’s gain (dBi) in the elevation plane for Φ=0˚ and frequency 1.9 GHz

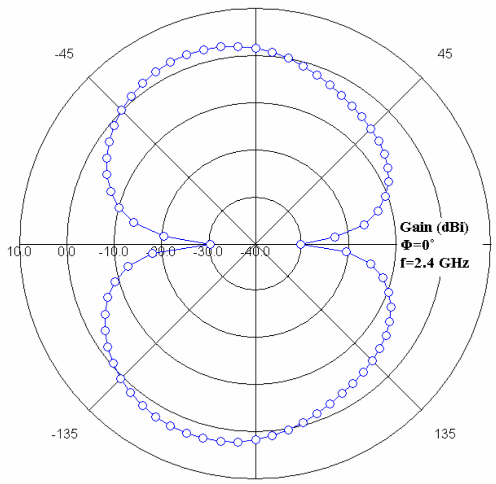

Fig. 18 Antenna’s gain (dBi) in the elevation plane for Φ=0˚ and frequency 2.4 GHz

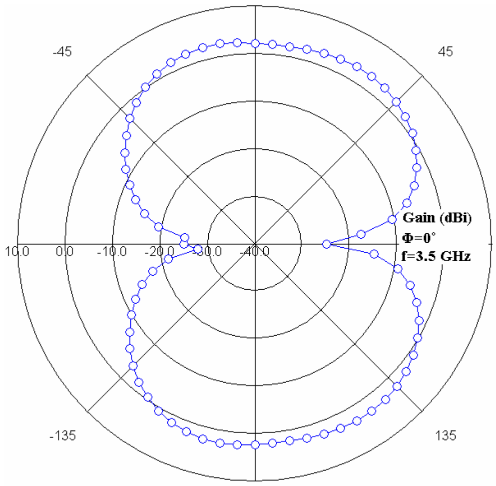

Fig. 19 Antenna’s gain (dBi) in the elevation plane for Φ=0˚ and frequency 3.5 GHz

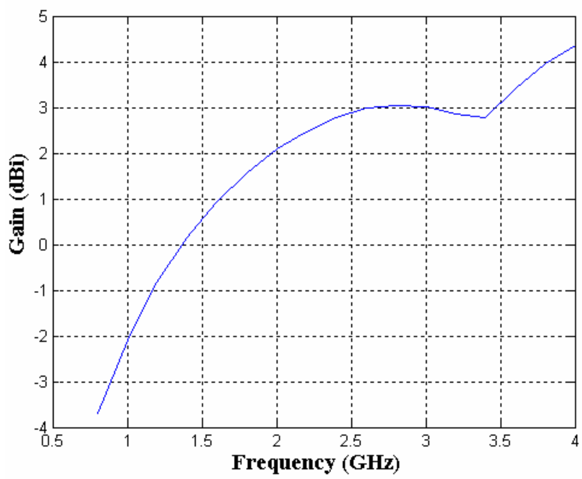

Fig. 20 Antenna’s peak gain (dBi) in the 0.8 – 4 GHz range

V. CONCLUSION

In this paper, a novel wide-band planar antenna for multi-standard mobile handsets is proposed. The antenna's geometry, characteristics and also designing steps with their effects are presented. The proposed values for the antenna's parameters achieve the paper's objective and can be considered start-values in a future optimization process.

It is shown that the proposed antenna can continuously operate in the wide-band from 890 MHz to 4100 MHz, which covers most of the communication systems such as GSM, GPS, DCS, PCS, UMTS, WLAN, WIMAX, etc. Due to its wide operating band and also to its small occupied volume, the proposed antenna it is applicable to the integrated multi-function mobile handsets.

The novelty of the proposed antenna is its bandwidth performance 4.6:1 and the elements used in obtaining it while keeping small physical dimensions: the wide-band matching circuit (the fork shape bridge) and the multi-resonance structure (the rectangular patch with the two symmetrical rectangular slots).

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