Wideband planar plate monopole antenna with dual tunable notch

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A tunable dual notch planar plate monopole antenna operating over 3–16 GHz bandwidth is introduced. To create the notch, a modified U-slot is placed on the monopole plate. Owing to the narrow width of the modified U-slot several slots can be placed on top of each other to create multiple notch-bands over the antenna operating bandwidth. The results for an antenna with two modified U-slots are presented. By placing a small capacitor on each of the slots in a suitable position, it is shown that the centre frequency of each notch can be individually shifted downwards by up to 2 GHz, without changing the notch-bandwidths. Simulated as well as measured results are presented and compared.

Introduction: Over the past few years there has been a rapid growth in the design of microwave antennas that can operate over a broad bandwidth. Over this bandwidth, there are a few narrow bands, such as WiMAX, Wireless Local Area Network (WLAN), HYPERLAN/2 systems, etc., that are allocated for certain applications that need to be filtered from the bandwidth of the antenna. It is desirable for the antenna to have this filtering capability without introducing extra circuitry. Several antennas with band-notch characteristics have been investigated.

A wideband antenna that has received much attention, owing to its simplicity in design, low cost of fabrication and which has an omni-directional pattern, is the planar plate monopole antenna. Versions of this antenna can cover the 2–16 GHz band [1, 2].

One of the techniques to create multiband behaviour in the planar plate monopole antenna is by cutting a slot inside the antenna. Most of the work reported so far is based on the simple U-shaped slots [3–7], the width of which covers the whole width of the monopole plate antenna. To create multiband notches requires placing more U-slots within each other. This limits the antenna to having up to two band notches. Furthermore, the simple U-slots cannot create a notch near the lower limits of the antenna bandwidth.

In this Letter, a multiband tunable notch planar plate monopole antenna is proposed. The notch is created by using a modified U-slot (MU-slot). The shape of the MU-slot is such that several slots can be placed on top of each other over the width of the monopole antenna, resulting in multi-notch behaviour. The notch centre frequency can be tuned either by changing the parameters of the MU-slot or by placing a small capacitor at a particular position along the MU-slot. The latter has the advantage that once the monopole antenna is constructed, by a capacitor we can easily change the notch centre frequency. Simulation results based on the software package HFSS along with experimental results are provided and discussed.

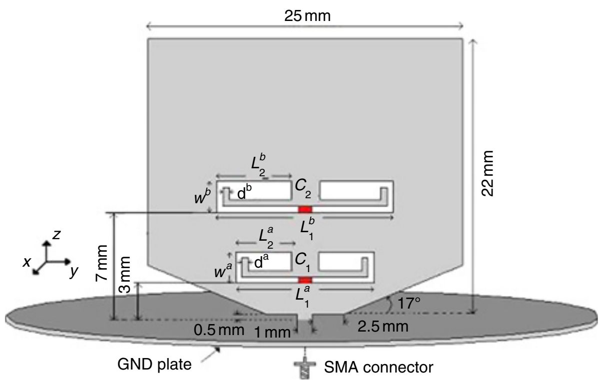

Fig. 1 *Planar plate monopole antenna loaded with multiple modified U-slots with capacitors*

Antenna design: To create a notch in the antenna bandwidth, one can use a modified version of a simple U-slot. In the MU-slot, the vertical arms of the U-slot are wrapped around itself creating a lower width slot. To create multi-notches, one can place the MU-slots on top of each other. By adjusting the geometrical parameters of the MU-slots and the slots' relative positions on top of each other one can obtain the desired notch centre frequencies and bandwidths.

Fig. 1 shows the proposed antenna structure. The antenna considered here uses two MU-slots to create two notches but extension to four notches can easily be carried out. In this work, a copper planar element of thickness 0.2 mm, size 22 × 25 mm and bevelling angle of 17°, is vertically mounted $s = 0.5$ mm over a 40 mm radius circular ground plane. A 50 Ω SMA connector, centrally mounted from the back of the ground plane, excites the antenna. The specification of the two MU-slots is: $L_1^a = 11$ mm, $L_1^b = 14$ mm, $L_2^a = 4.75$ mm, $L_2^b = 6.25$ mm, $W^a = W^b = 2.5$ mm, $d_1^a = d_1^b = 0.5$ mm. Parameters such as L_1 and W greatly affect the notch centre frequency. The positions of the two slots above the ground plane, for an appropriate notch level and bandwidths, are found to be 3 and 7 mm.

To tune the notch centre frequencies one can place small capacitors at the centre position of the MU-slots, as shown in Fig. 1. Viewing the MU-slot from the centre, one can model each arm by a short-circuited quarter wave transmission line operating at the centre frequency of the notch. The reactance of this capacitor at the centre position would be in parallel with the equivalent transmission line. Through this simple model one can see that introduction of the capacitor shifts the notch centre frequency downwards.

Results: The simulated return loss of the planar monopole antenna with two MU-slots is shown in Fig. 2. Based on the parameters chosen for the MU-slots, two notches, one narrow band at 4 GHz and the other a wider band at 5.5 GHz are seen. The effect of placing a capacitor on each of the MU-slots is also shown in Fig. 2. The two capacitors are set equal to each other. It is noted that placement of the capacitors reduces the notch centre frequencies without affecting the notch bandwidth. For an increase of 0.1 pF in capacitance, the notch centre frequency of each band drops by an amount almost equal to its bandwidth.

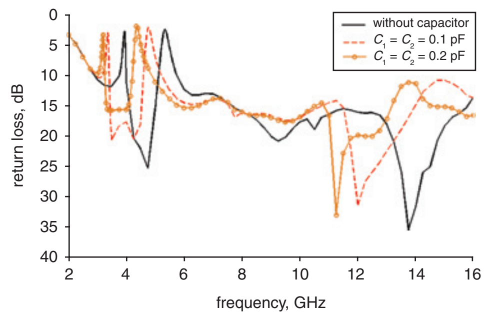

Fig. 2 *Return loss of planar plate monopole antenna with pair of modified U-slots with various* C_1 *and* C_2.

Fig. 3 shows the return loss of the antenna when capacitor C_1 is fixed while the other, C_2, changes. Results show that the lower notch does not change in frequency while the upper notch centre frequency changes. Also, this Figure shows that there is a low mutual coupling between the two notches with the presence of the capacitors. Similar results are obtained if C_2 is fixed while C_1 is changed.

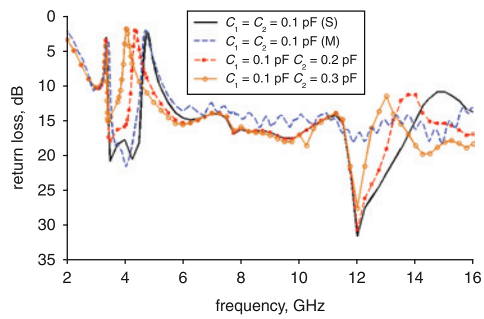

Fig. 3 *Return loss of planar plate monopole antenna with pair of modified U-slots with constant* C_1 *and variable* C_2

S: simulation
M: measurement

Fig. 4 shows the gain of the planar monopole antenna with MU-slots with and without the capacitors. It is noted that the presence of the capacitors only shifts the notches and the gain does not change much.

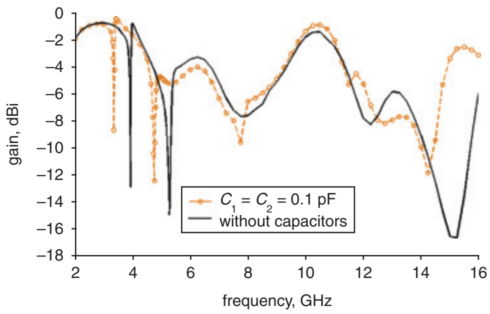

Fig. 4 *Simulated broadside gain of monopole antenna with pair of modified U-slots with and without capacitors*

Finally by increasing each of the capacitor values to 5 pF, the relevant notch can be removed from the antenna bandwidth.

Conclusions: A multiband tunable notch planar plate monopole antenna is presented. Owing to its small width, stacking such MU-slots on top of each other leads to multiple notch resonances. By placing a capacitor on the centre of this type of slot, notch centre frequencies shift to lower frequency without change in notch bandwidth. If a varicap is used, the notch centre frequency can be electrically adjusted. The measured results are in good agreement with the simulated results.

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

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