ULTRA WIDEBAND PLANAR MONOPOLE ANTENNA WITH CONTROLABLE NOTCH

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Abstract: A tunable notch through the use of a short circuited small modified U-slot in a wideband, 3-16GHz, planar monopole plate antenna is presented. By placing the shorting pin in a suitable position on the MU-slot, centre frequency of the notch can be controlled. If the shorting pin is located in the centre of the modified U-slot, the notch can be removed. The proposed monopole antenna loaded with shorted modified U-slot is modeled through transmission line theory. Based on slot equivalent current length and shorting pin location, a formula for the notch centre frequency is given. The results of simulation and measurement are presented and discussed.

Introduction: The existing WiMAX system with frequency of 3.5 GHz, Wireless Local Area Network (WLAN) and IEEE 802.11a systems over the band 5.150 – 5.875 GHz, HYPERLAN/2 systems over 5.725– 5.825GHz, etc. can cause interference with the very wide band communication systems. To avoid interference a band stop filter in the wideband communication system is necessary. To reduce the complexity of the electronic circuits, band-notching technique can be applied directly to the antenna.

A simple and low cost antenna suitable for wide band wireless application is the planar plate monopole antenna. One technique that is used to create a notch is to cut a slot inside the planar monopole antenna. Different slot configurations such as *U*, *I*, *V* and crescent shape have been introduced [1-5], of which the U-slot has received more attention. For a given vertical length of the monopole plate antenna, there would be a limit to the vertical length of the U-slot that can be placed on the antenna. Thus, a notch near the lower frequency band of the antenna cannot be achieved. Furthermore, as to obtain multi notch behavior (more than two) several U-slots should be placed within each other, making the fabrication of the U-slots very difficult. To create dual bands, combinations of such slots have been introduced [6-8].

In this paper, a novel modified U-slot (MU-slot) that uses a smaller compact slot for a given notch centre frequency as compared to a conventional U-slot is proposed. By varying the parameters of the MU-slot a tunable notch over the 3-16GHz band can be obtained. The MU-slot shape with its low vertical length and long effective perimeter length (long current path) can result in a notch even at the lower frequency limit of the antenna. Control over the notch centre frequency can also be achieved through placement of a shorting pin across the slot leading to a shorted modified U-slot (SMU-slot). Simulation results via commercially available software packages HFSS and ADS and measured results are provided and discussed.

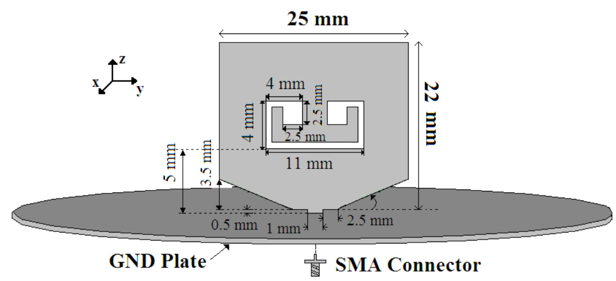

Fig. 1 The planar plate monopole antenna with a modified U-slot.

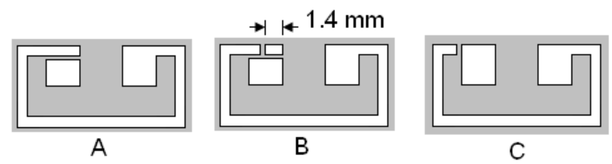

Fig. 2 Different configuration of the shorted modified U-slot

Antenna Design: A band notch characteristic in the planar monopole antenna bandwidth can be created by placing a U-slot on the antenna. To have a smaller slot, one can wrap the arms of the U-slot around itself. Fig. 1 shows the proposed antenna structure. It consists of a planar wideband monopole antenna with a MU-slot shape. The planar monopole antenna was developed in [1]. There are a number of parameters that influence the bandwidth; these include the size of planar monopole, the feeding gap, the beveling and the size of the ground plane. In this work, a 40 mm radius circular ground plane is used. A 50 ohm SMA connector, centrally mounted from the back of the ground plane, is used to excite the antenna. A copper planar element of thickness, 0.2 mm, size 22mm × 25 mm and beveling angle of 17°(or h_b=4mm), is vertically mounted s=0.5 mm over the ground plane. To implement the notch characteristic, MU-slot is placed on the planar antenna. It will be shown that one can tune the notch center frequency by

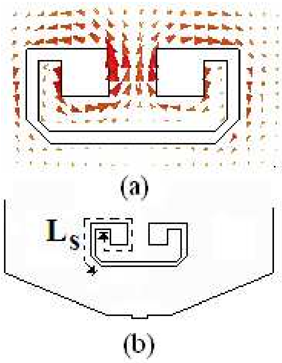

Fig. 3 (a) Current distribution over the monopole antenna at notch centre frequency and (b) effective current length, L_S.

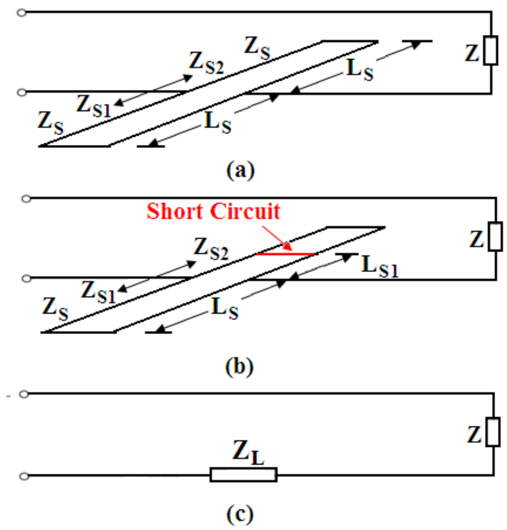

Fig.4 Transmission line model of the monopole antenna loaded with (a) Modified U-slot and (b) One arm shorted Modified U-slot. (c) The equivalent circuit.

placing a shorting pin in a suitable position on the MU-slot structure. Three different positions of the shorting pin on the MU-slot are shown in Fig. 2.

Band-notch characteristic: The simulated normalized surface current distribution over the planar monopole antenna loaded with the MU-slot operating at notch centre frequency is shown in Fig. 3(a). This figure shows that at notch centre frequency the current concentrates around the wrapped MU-slot. Figure 3(b) shows the effective current path length, *Ls*. According to [2-4], the centre frequency of the notch can be related to this current path length through the following formula:

$$f_{notch} \cong \frac{c}{4 \times Ls} \qquad (1)$$

Based on the antenna behavior at notch centre frequency, one can consider a transmission line model. This includes the antenna radiation impedance, Z, in series with an equivalent stub, as shown in Fig. 4(a).

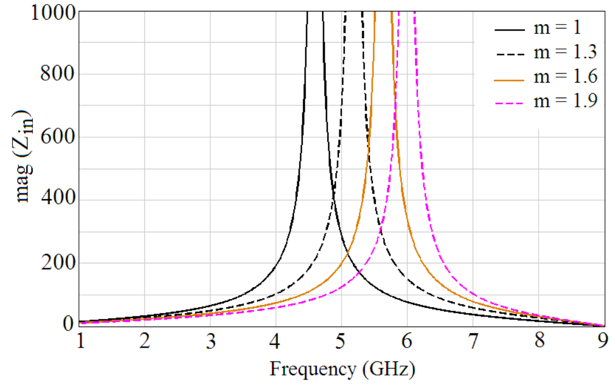

Fig. 5 Simulated input impedance of the equivalent circuit of Fig. 4(b) with m = L_S/L_{S1}.

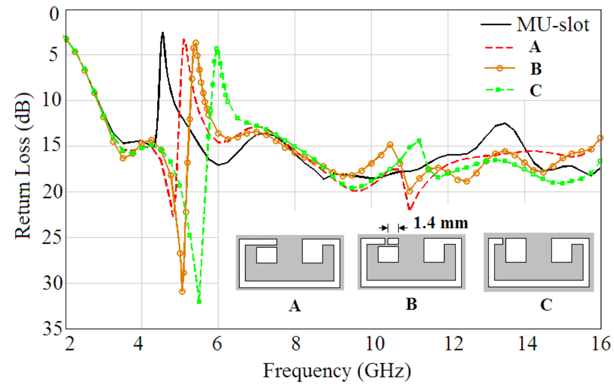

Fig. 6 Simulated return loss of the antenna with MU-slot and SMU-slot.

Each half of the slot can be modeled by a shorted stub with length, L_S equal to quarter-wavelength at notch centre frequency. Fig. 4(b) shows the equivalent transmission line model of the planar monopole antenna loaded with a single shorted modified U-slot. The shorted stub with length, L_{S1} is related to the shorting pin position along the slot. The equivalent impedance, Z_L of the two parallel sections of the slot halves is shown in Fig. 4(c). Equation 2, through transmission line theory, gives Z_L. In this equation λ_S is the wavelength at notch centre frequency.

$$Z_L = Z_{S1} \| Z_{S2} = (jZ_S tg(\frac{2\pi L_S}{\lambda_S})) \| (jZ_S tg(\frac{2\pi L_{S1}}{\lambda_S})) \qquad (2)$$

Figure 5 shows the simulated magnitude of the input impedance of the transmission line model of Fig. 4(b) as obtained through Advanced Design System package. In this figure *m* represents the ratio L_S/L_{S1}. The results show that by increasing *m* the peak of the input impedance shifts towards the upper frequency. Thus, by changing the position of the shorting pin, one can easily shift the notch centre frequency.

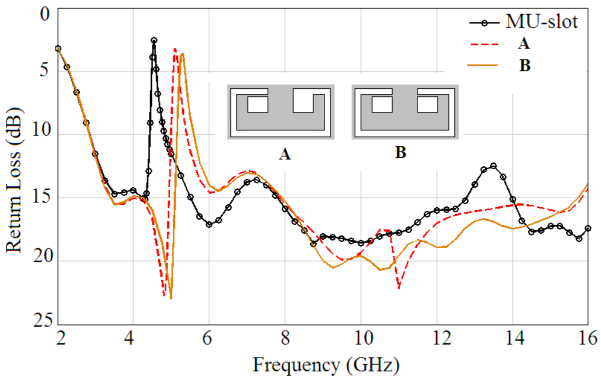

Fig. 7 Simulated return loss of an antenna with single shorted MU-slot and symmetrically shorted MU-slot.

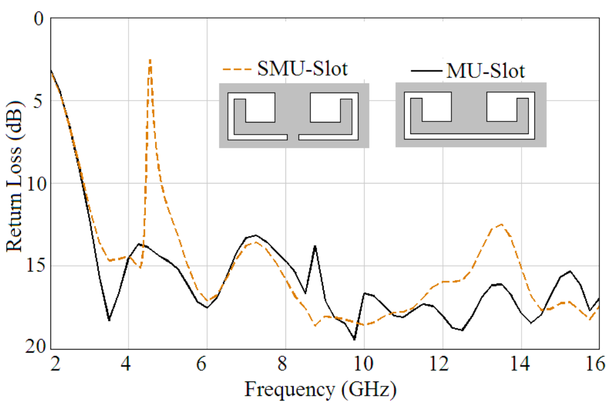

Fig. 8 Simulated return loss of an antenna with MU slot and MU-slot with shorting pin in center of the slot.

Simulation and measurement result: Figure 6 shows the return loss result of the MU-slot and the SMU-slot. The shorting pin is placed in three different positions along the slot. From the results it can be seen that placement of the shorting pin reduces the current path length and shifts the resonance frequency of the notch upward. Also, the position of the shorting pin affects the notch centre frequency. Thus for a given MU-slot, placing a shorting pin at a particular position along the slot, the desired notch centre frequency can be obtained.

If two shorting pins are placed symmetrically along the slot, as shown in the caption of Fig. 7 structure B, the current path length on each arms of the slot becomes shorter making the notch center frequency shifts even upper compared to that of structure A in Fig. 7.

Based on equation 2, one can see that when the shorting pin is placed in the center of the slot, slot impedance, Z_L, becomes zero, and as shown in Fig. 8, notch can be removed.

To create two notches, we usually employ two different sized MU-slots on top of each other. If the shorting pin is used, one can employ two same size MU-slots on top of each other, with one slot being shorted via a shorting pin, as shown in Fig 9. In this figure, the shorted slot in structure A and B is fixed in position on the monopole antenna. This figure displays that this

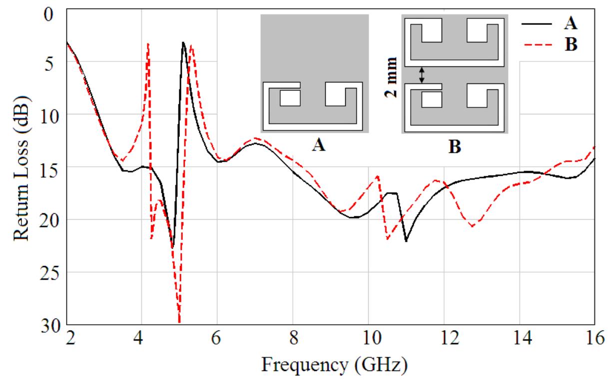

Fig. 9 Simulated return loss of antenna with single shorted MU-slot and two MU-slots with single shorting pin.

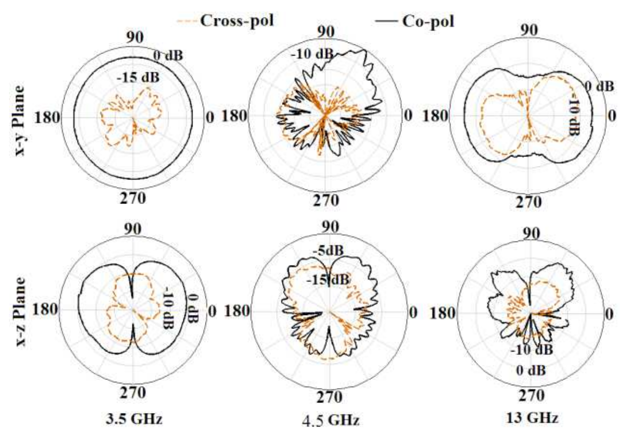

Fig. 10 Measured radiation pattern of monopole antenna with MU-slot

configuration can create two notches over the bandwidth. Also this figure shows that there is a slight amount of mutual coupling between the two slots. This coupling causes a slight shift in the resonance frequency of the notch.

Figure 10 shows the measured co and cross polar radiation patterns of the monopole antenna with single MU-slot at three frequencies, 3.5 and 13GHz (pass band frequencies) and 4.5 GHz (the notch frequency). It can be seen that the cross polar level is well below the co-polar level at pass band centre frequencies.

The shorting pin discussed above, practically, can be a pin diode in which if a voltage is applied across it, it behaves either as a short circuit or as an open circuit. By placing several of such diodes along the slot, one can easily control the notch centre frequency within the antenna bandwidth.

Conclusion

A novel modified U-shaped slot with shorting pin to produce a tunable band notch behavior in the wideband planar plate monopole antenna has been given. By stacking such MU-slots on top of each other multiband behavior is obtained. The position of the shorting pin determines the centre frequency of the notch. The measured results are in agreement with the simulated results.

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