5.2 GHz notched ultra-wideband antenna using slot-type SRR

J. Kim, C.S. Cho and J.W. Lee

A band notch characteristic using a slot-type split ring resonator (SRR) working at microwave frequencies is used for designing a UWB antenna requiring the rejection of some frequency band, which is already in use by existing wireless services. The slot-type SRR is employed effectively for notching unwanted frequency band such as that for WLAN service, since it can be implemented with a small dimension and in a high Q operation similarly to the conventional strip-type SRR. Based on the simulation and measurement results, a band notched UWB antenna using a slot-type SRR is very effective in rejecting unwanted frequency in terms of its selectivity and small real estate.

Introduction: Pendry capitalised on the split ring resonator (SRR) structure for the first time to construct the left-hand materials where the electromagnetic wave behaves in a reverse way, with respect to the conventional rule, from right-handed materials [1]. Using this characteristic, various exotic circuits have been developed, which were assumed to be unrealisable until then. In this sense, the SRR provides a particular interest, specifically in its resonant behaviour. Since the SRR can be considered as an electronically small resonator with a very high Q, it is a very useful structure in constructing filters requiring a sharp notch or pass of a certain frequency band. The SRR also has resonance and anti-resonance properties inherently that can pass or stop the flow of the electromagnetic field that is polarised and localised along the SRR array, because the SRR has a resonance permeability and anti-resonance permittivity [2].

In the work described in this Letter, the SRR is modified to a slot-type structure for rejecting unwanted frequency band in a UWB antenna, maintaining its high Q characteristic and small real estate. Therefore, a slot-type SRR is eventually developed for a band notched UWB antenna, since the UWB service operates in a wide frequency band, such as from 3.1 to 10.6 GHz, where some frequency band pre-occupied by the WLAN should be avoided.

Design of slot-type SRRs: The SRR is generally composed of two concentric split ring strips, which are under investigation by researchers to implement left-hand materials. In this research, we take advantage of its theory and experimental results that have been already proven and realised. Instead of the conventional strip-type SRRs, a slot-type SRR is proposed and implemented for a bandstop application, since it provides high Q characteristic, similarly to the strip-type SRR.

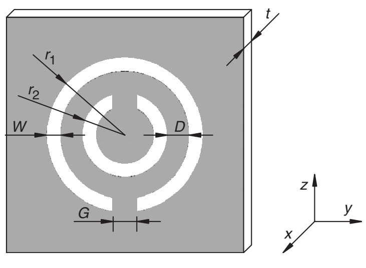

Fig. 1 *Geometry of proposed slot-type SRR*

The published work that has mentioned the SRR in both theoretical and experimental aspects [3, 4] is utilised as a design guideline to determine the geometry of the slotted complementary form of the SRR on a conducting plane. If an electromagnetic wave polarised in the y-axis propagates in the z-direction, as in Fig. 1, the SRR can be symmetrical in the z-axis. Under this condition, using the same approach given in [5], the resonance frequency can be postulated as

$$\omega_0 = \sqrt{\frac{2}{\pi r_0 L_0 C}} \qquad (1)$$

where L_0 is the inductance per unit length between the annular slots, C is the total capacitance of the SRR, and r_0 is the average radius of the two annular slots.

We take (1) into account in obtaining the dimension of the SRRs at the very beginning of the design and then adjust the geometry for the final design. The average circumferential length of the slotted rings appears to be shorter than a half wavelength at resonance. The average circumferential length of the SRR plays a dominant role in determining the resonance frequency. The behaviour of the slotted complementary SRR is very similar to that of the SRR. The complementary SRR can create the strongest resonance when parallel polarisation occurs, where the parallel polarisation means that the E-field is aligned parallel with the y–z plane and the H-field is aligned with the centre axis (x) of the complementary SRR.

Band notched UWB antenna: A new design of bandstop UWB antenna is presented in this Letter, as shown in Fig. 2. Since the SRR has a favourable aspect in its size, it can be designed as small as one-tenth of the resonance wavelength. Using this advantage of small real estate, outstanding performance can be realised for broadband antennas, which are now widely demanded in UWB applications.

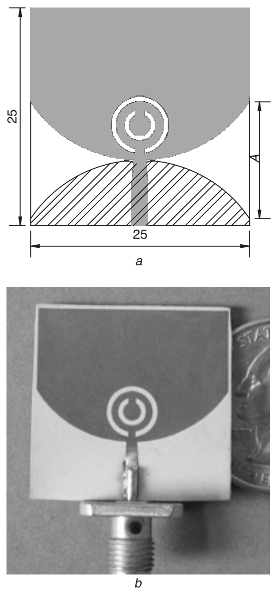

Fig. 2 *Geometry of band notched UWB antenna*

a Dimensions (solid: upper conductor, hatched: lower conductor, and dimensions in mm)
b Fabricated antenna

The frequency range 3.1–10.6 GHz is of interest for UWB service and thus an extremely broadband antenna will be launched in this band. However, there may be some other existing narrowband services that already occupy frequencies in the UWB band. Several methods and structures have been proposed to avoid a frequency collision with the narrowband services, such as WLAN, by adding a filtering structure to the antenna. So far, several design methods for blocking frequency have been reported, but there is no method to increase their selectivity [6, 7].

The approach presented in this Letter has advantages in frequency selectivity and real estate of the complementary SRR. It is expected that, in general, the smaller structure can have a relatively smaller effect on the radiation patterns of the antenna.

From the guidelines mentioned before, the dimensions of the slotted SRR, as shown in Fig. 2*a*, were obtained as $r_1 = 3.3$ mm, $r_2 = 1.8$ mm, $W = 0.6$ mm, $D = 0.9$ mm and $G = 1$ mm, in order to have the band notch from 5.15 to 5.35 GHz, the higher band assigned for the wireless LAN. The slotted SRR was positioned near the feeding point to provide more coupling with the field. The total size of the UWB antenna is 25×25 mm and its aperture width is $A = 13.5$ mm, to cover the UWB band from 3.1 to 10.6 GHz. The design has been fabricated on RO6003 ($\varepsilon_r = 3$), with $t = 0.762$ mm, by photo-etching, as shown in Fig. 2*b*.

Experimental results: To verify the performance of the proposed approach, the band notched UWB antenna was measured after fabrication. The return losses of the simulation with Ansoft-HFSS and the measurement are shown comparatively in Fig. 3. An additionally designed UWB antenna using the same geometry without the SRR configuration was also fabricated for comparison with the SRR band notched antenna. According to the measured return loss, the UWB antenna covers the band assigned for the UWB application. The measurement shows that the stopband of the band notched UWB antenna has about 0.6 GHz bandwidth with a reference level of $|S_{11}| = -7$ dB and the centre frequency of the notched band is 5.2 GHz at which the wireless LAN service is assigned. The radiation patterns of the E-field for three different frequencies are shown in Fig. 4, where the receiving power level is relatively very low at 5.2 GHz. The maximum gains are shown in Fig. 5. As expected, the maximum gain is the lowest in the vicinity of 5.2 GHz. Very sharp selectivity was observed in both the return loss and the gain. The typical characteristics of SRRs, a small real estate and a sharp selectivity, were observed from the experimental results of the band notch antenna. In addition, it is expected that, in general, the smaller slot structure can affect the radiation patterns of the UWB antenna less than the existing approaches [6, 7].

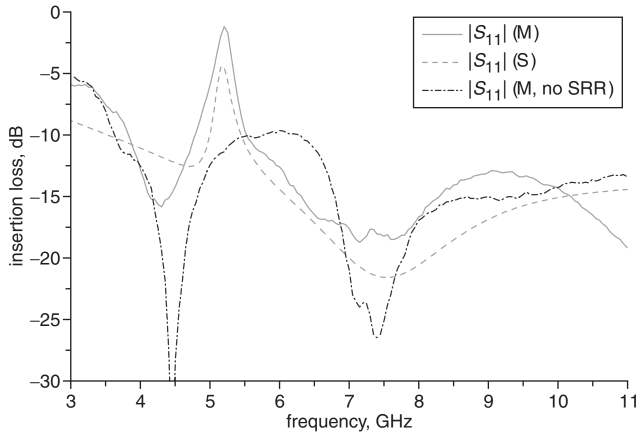

Fig. 3 *Insertion losses of band notched UWB antenna and identical UWB antenna except SRR*

M: measurement, S: simulation by HFSS

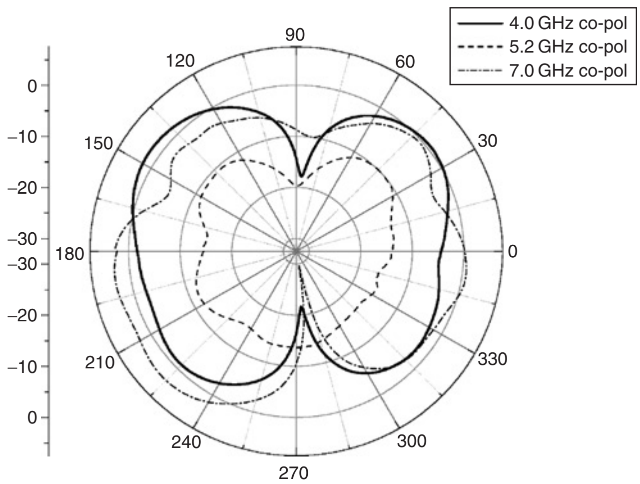

Fig. 4 *Radiation patterns on E-plane (x–z plane) at 4, 5.2 and 7 GHz*

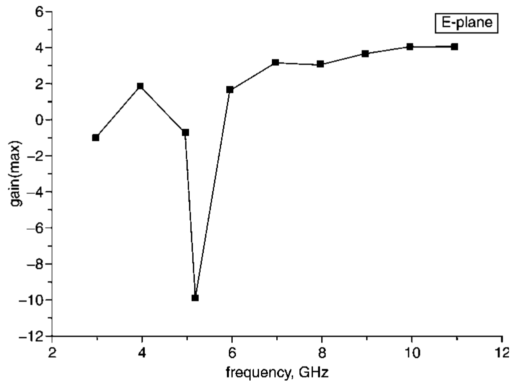

Fig. 5 *Maximum gain for radiation patterns in E-plane*

Conclusions: The very sharp notch performance and small real estate provided by the slotted SRR UWB antenna have been realised successfully using the design philosophy proposed in this Letter. Other than UWB antennas, the slotted SRR can be utilised for various applications demanding band rejection and small geometry.

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