Electrically small antenna by Coupled magnetic resonances

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By stacking multiple split-ring resonators (SRRs), an electrically small antenna (ESA) is designed. Without the matching network, such an ESA is shown to be matched to the source load naturally, due to the resonance of the Split-Ring Resonators (SRRs). With stacking technique, it is shown that SRR based ESA can radiate more efficiently than those conventional ones.

The schematic of the stacked SRRs are shown in Fig.1(a). The ESA's resonant frequency is effectively lowered by stacking multiple SRRs with strong magnetic coupling. In case the number of SRRs increases from 1 to 6, the resonant frequency of the antenna gradually decreases, as shown in Fig.1(b). We emphasize that this multi-layered structure is realizable in the multi-layered PCBs and the 3D integrated circuits.

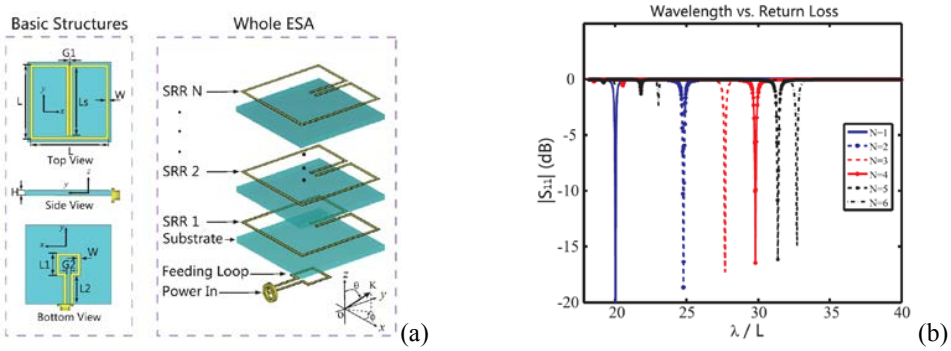

Figure 1. (a) The schematic show of an antenna made of SRRs with strong magnetic coupling. (b) The operation frequency reducing with increased SRRs.

This phenomena is well explained through the standard coupled mode theory, which is briefly shown as:

$$a_1'(t) = i\omega_1 a_1(t) + i\kappa_{12} a_2(t)$$
$$a_2'(t) = i\omega_2 a_2(t) + i\kappa_{21} a_1(t).$$

As well the total radiation efficiency of this antenna can be formulated to be

$$\eta = \{1 + \frac{12\pi R}{Z_0 k^4 S^2} \frac{\sum |I_n|^2}{(\sum I_n)^2} + \frac{12\pi}{Z_0 k^4 S^2} \frac{P_d}{(\sum I_n)^2}\}^{-1}.$$

It is seen that if the current on each of the SRRs are identical, the radiation efficiency would grow as the number of the stacked SRRs inceases.

The approach proposed, with applying the strong magnetic coupling, to shrink the antenna's overall size, meanwhile to promote the radiation efficiency, is very helpful in designing the electrically small antennas with superior performance. Simulations and experiments verify the justification of our new findings.

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