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Dual-band WLAN Antenna Array with Integrated Filters for Harmonic Suppression

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Abstract:

This paper presents the design, modelling and results of a dual-band antenna array integrated with filters. The array is fed via a single 50 Ω port and consists of two radiating elements. Hence, a 1x2 array structure. The two bands of the antenna array correspond to the two WLAN bands of 2.4 GHz and 5.8 GHz. Other than the two fundamental resonant frequencies, the standalone array has spurious harmonics at various other frequencies. For the suppression of these harmonics, the array is integrated with two bandpass filters, centered at 2.4 GHz and 5.8 GHz. The antenna array with integrated filters was electromagnetically modelled and the simulation results have been presented. The acquired results are considerably acceptable; showing the array to have dual-bands at 2.4 GHz and 5.8 GHz, at a return loss of more than 20 dB, and also successful suppression of the spurious harmonics of the antenna array.

I. Introduction:

An antenna is an integral part of all wireless communication devices. When two or more antennas are combined in a single structure, it is known as an antenna array. An array is better than a single antenna; primarily since it is more powerful with regards to transmitting and receiving signals, performing multiple tasks at the same time and also because it shares the same feed network for the radiating elements, rather than having individual feed networks for multiple antennas. The WLAN operates at 2.4 GHz and 5.8 GHz as defined by the IEEE 802.11a/b/g/n/ac standards [1]. Currently, the 2.4 GHz and 5.8 GHz point-to-point antenna arrays are mounted separately with discrete ports [2]. It is difficult to achieve a broadband planar antenna array with stable directional radiation patterns from 2.0–6.0 GHz, as gain is proportional to radiation aperture [2]. Hence, a dual-band array structure is preferred due to its simple system configuration and cost minimisation. Although similar work is proposed in [2] and [3], but is disadvantageous with respect to a few qualities; such as, 3rd order filters being used, larger 2x2 array structures, single-band operation and final response not being sufficiently sharp. In this presented work, a dual-band 1x2 antenna array with 2nd order integrated filters is designed, modelled and simulated. Initially, a standalone array (array without filters) - fed by a single feed network - was designed and was shown to possess spurious harmonics in addition to the two main resonant frequencies. Hence, bandpass filters were chosen to be integrated within the array. The filters would serve to allow the wanted frequencies to pass through, while rejecting all others. Hence, the spurious harmonics would be removed. The designed antenna array utilises microstrip technology. The organisation of the paper is as follows. In section II, the design of the proposed structure is detailed. Section III presents the results. The conclusions of the work follow in section IV.

II. Design of Antenna Array, Filters and their Integration:

The proposed standalone antenna array is illustrated in Fig. 1. The array consists of two antenna patches, modelled to have fundamental resonant frequencies at 2.4 GHz and 5.8 GHz by using the design equations given in [4]. The two patches are joined to 50 Ω transmission lines via quarter-wave transformers. The whole structure is fed by means of a single 50 Ω port. The power from this port is split in to two branches through a 76.71 Ω transmission line. The length of this power-splitting transmission line is dependent on the spacing between the two patch antennas. The two patch antennas are spaced at a distance of $0.5\lambda_g$ in order to minimise mutual coupling; where λ_g is the guided wavelength at the smaller operational frequency, i.e. 2.4 GHz. The two designed patch antennas are then connected to the two ends of the power-splitting line; thus forming a 1x2 antenna array.

The bandpass filters have a pseudo-interdigital structural shape and are of second order each. Their basic design is shown in Fig. 2. The values (in mm) of the parameters in the figure for 2.4 GHz are: *L1=3.5*, *L2=23.8*, *L3=1.5*, *W1=2.2*, *W2=0.3*, *G1=0.9*, *G2=0.3* and for 5.8 GHz are: *L1=3.5*, *L2=8.3*, *L3=3.4*, *W1=2.2*, *W2=0.6*, *G1=0.3*, *G2=0.8*. The 5.8 GHz filter was chosen to have a narrow passband. This is advantageous because upon integration with the array, a sharp response and better rejection of the spurious harmonics would be achieved. Comparatively, the 2.4 GHz filter has a slightly wider passband than the 5.8 GHz filter. This is attained by using thinner width for the interdigital fingers and less spacing between the fingers. This is done in order to achieve two things: to minimise any mutual coupling between the two filters and to minimise the overall length of the entire structure.

With the aim of forming an antenna array with integrated filters for spurious harmonics rejection, the two designed bandpass filters are combined in the array next to the power splitting line. The power-splitting transmission line acts as a feedline for both filters. Furthermore, since the integration causes the overall width of the structure to increase substantially, the distance between the two patch antennas is decreased from $0.5\lambda_g$ to $0.33\lambda_g$; where λ_g is the guided wavelength at 2.4 GHz. The ensuing final structure is illustrated in Fig. 3. When the 50 Ω port of the resulting structure is excited, current flows in and then gets divided in to the two branches. Since the two branches are feedlines of the two filters, the current then flows in to the two filters through coupling. Each filter then lets pass through only its respective frequency, while rejecting all others. Lastly, the two patch antennas radiate at their particular resonant frequencies, which are the same frequencies passed out by the two bandpass filters.

III. Results:

All the proposed structures are designed on a Rogers RT5880 substrate of thickness 0.79 mm, having a dielectric permittivity $\varepsilon_r = 2.2$ and dielectric loss tangent $\tan\delta = 0.0009$. They are modelled and simulated using the commercial software emSonnet. The simulated results of the standalone array are presented in Fig. 4. The dominant mode resonant frequencies are at a return loss of almost 30 dB each. As can be also seen, other than the resonant frequencies, there are spurious harmonics present at various other frequencies. These harmonics interfere with the main signals and cause distortion as well as loss of sensitivity.

The simulated S-parameters of the bandpass filters presented in Fig. 5 and Fig. 6 show that the filters are centered at 2.4 GHz and 5.8 GHz. The results also show the filters' 3 dB passband to be 2.08–2.69 GHz and 5.51–6.11 GHz and hence have fractional bandwidths of 25.4% and 10.4% respectively. The simulation results show the insertion loss to be about 0.1 dB in the both passbands. Transmission zeroes appear at frequencies below and above the passbands of both filters. The transmission zeroes improve near-bandwidth rejection. The return loss is more than 13 dB for most of the passband bandwidth in both filters.

The simulation results of the antenna array with integrated filters are shown in Fig. 7. The results show the proposed structure to have dual-band fundamental resonant frequencies and a major suppression of the spurious harmonics has been achieved, as desired. However, the pick at 4.5 GHz has not been fully rejected. This can be countered by shifting forwards the first transmission zero of the 5.8 GHz filter. Although the required results have been obtained in terms of harmonic suppression, the return loss of the antenna array at the two dominant resonant frequencies has decreased by about 7.5 dB each, i.e. resulting at about 22.5 dB. This can be attributed to the extra metallisation of the integrated filters and extra couplings involved in the new structure.

IV. Conclusion:

In this paper, a WLAN dual-band 1x2 antenna array, integrated with two pseudo-interdigital bandpass filters, is designed and presented. A standalone antenna array was simulated and the result has been presented. It was found to have spurious harmonics in addition to the two main operational WLAN frequencies of 2.4 GHz and 5.8 GHz. The integrated filters are a means of rejecting the spurious harmonics that are present in the antenna array while keeping the two fundamental resonant frequencies intact. The simulation results of the two filters have been presented and show them to be centered at the two main frequencies. The two filters were then integrated within the standalone array. Simulation results of the antenna array with integrated filters have been shown and are as desired. Although the obtained results show a little reduction in return loss at the two fundamental frequencies, the suppression of the spurious harmonics in the antenna band has been satisfactorily achieved. The proposed modelling and design could be implemented for other filtering arrays.

References:

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Figures:

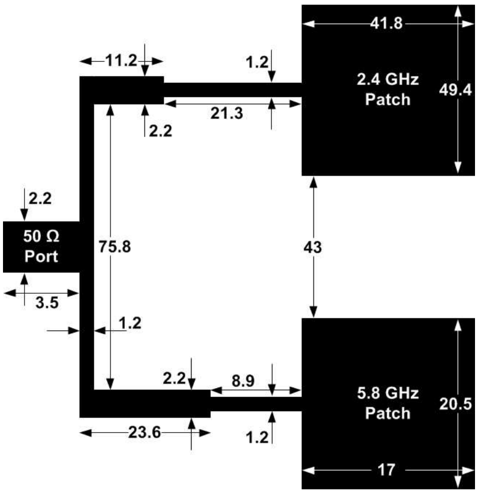

Fig. 1. Geometry of antenna array (dimensions in mm).

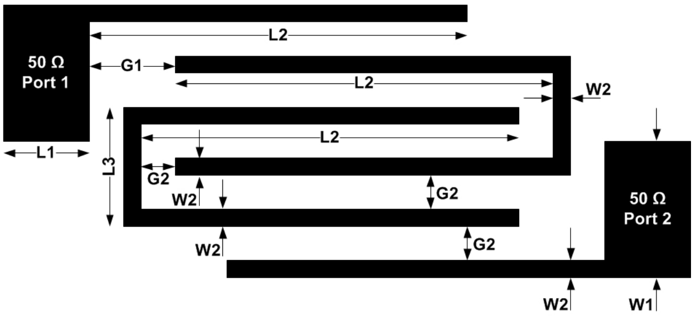

Fig. 2. Geometry of filters.

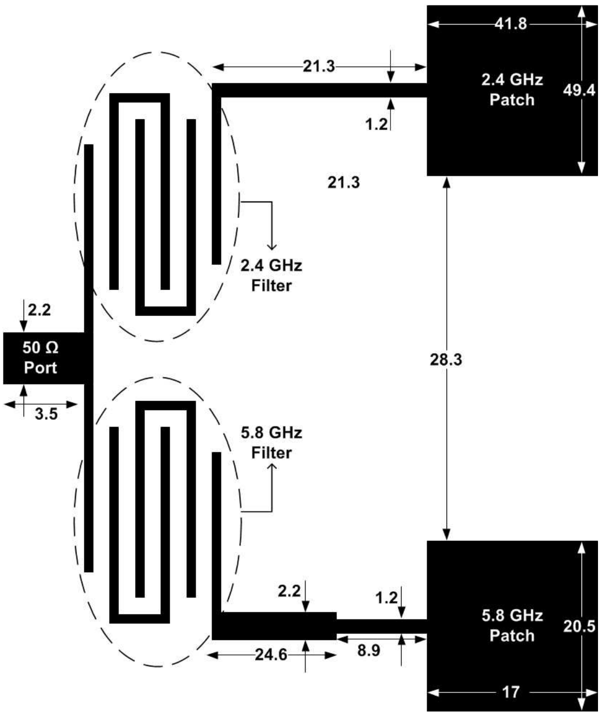

Fig. 3. Geometry of array with integrated filters (dimensions in mm).

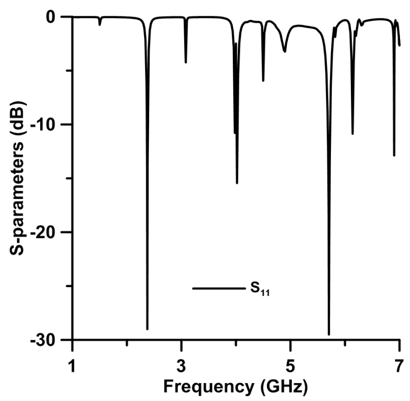

Fig. 4. S-parameters of antenna array.

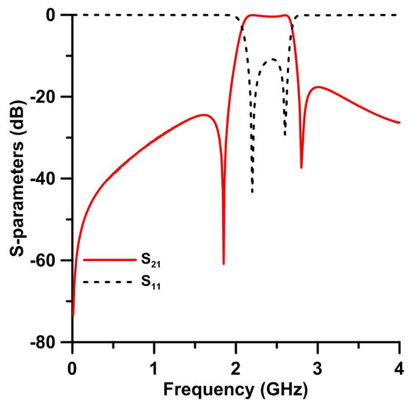

Fig. 5. S-parameters of 2.4 GHz filter.

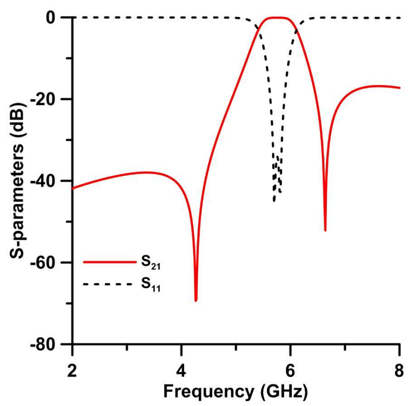

Fig. 6. S-parameters of 5.8 GHz filter.

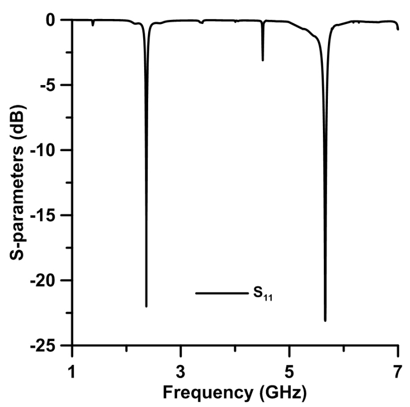

Fig. 7. S-parameters of antenna array with integrated filters.