A Low Profile and High Efficiency Antenna Array for WLAN at C-Band

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1. Introduction

A high gain planar array operating over the entire 802.11a WLAN band of 5.15 to 5.825 GHz is required to provide range extension for WLAN access points. In addition, a low profile and light weight planar array would improve its portability as well as the aesthetic aspect at its site of deployment. To satisfy these requirements, we have developed a very thin C-band array with dimensions of 18 x 18 x 0.65 cm possessing a symmetric main beam with peak gain of 20.3 dBi at mid-band. The cross-polar level is less than -30 dB and the decaying sidelobe structure is well behaved. The design of such an array is discussed below.

2. Array of Probe-fed Cavity-backed Patches

The preferred element to be used for a low profile array with 14% bandwidth is the probe-fed cavity-backed patch. Such an element exhibits axis-symmetric patterns with low cross-polar levels. The typical cavity-backed patch fed by the centre conductor of a standard SMA connector does not provide the required bandwidth. This is due to the relatively small size of about 0.4 to 0.45λ of the cavity fed by a very thin probe. Such a configuration performs the mode transformation from the TEM mode to the radiating TE10 mode at the patch interface thus resulting in narrowband performance. A larger cavity together with an appropriately enlarged diameter probe will facilitate the mode transition further back at the coaxial feed-cavity interface. Consequently, a much broader bandwidth is obtained.

A very accurate and fast method to analyze the performance of an array of probe-fed cavity-backed patches is the modal method. To apply this method, the modes of a rectangular waveguide with an off-set inner conductor need to be determined. The circular probe is converted to an equivalent square conductor. An electric and a magnetic wall are placed in the plane of symmetry. Only half the cross-section needs to be considered. The field distributions and mode cutoff wavenumber are determined by the transverse resonance technique for the TEM, TE and TM modes. Here the cross-section of the guide is decomposed into rectangular regions and the field distributions within each region are represented by a series of trigonometric functions with unknown coefficients. These field distributions meet the exterior boundary conditions. By matching the fields in the transverse direction across the internal section boundaries, we obtain the unknown coefficients that are subsequently normalized by the square root of the mode power. A complete description of each mode is thus obtained. The scattering matrix of each discontinuity in the longitudinal direction of propagation the radiating element is found by mode matching. Assuming that the modes are arranged in order of their cutoff wavenumber, the number of modes needed for convergence is set such that the cutoff wavenumber of the highest order mode is approximately 7 to 8 times that of the operating wavenumber. The scattering matrices of the various guide sections and discontinuities are combined together to yield a very accurate characterization of the element operating in an array environment.

3. Design of the C-Band Array

The size of the array is restricted to an area of about 18 x 18 cm. Thus a 6 x 6 array results with a cavity size of 2.97 cm or 0.63λ at mid-band and an element spacing of 3.09 cm. The diameter of the probe (0.100 inch), the y-displacement of the probe (0.27 inch), the height of the patch or probe (0.126 inch) and the patch size (0.84 x 0.84 inch) have been optimized to give a maximum active return loss of -11 dB across the band of operation in an array environment. The element height is kept to a minimum as a design goal.

The construction of the 6 x 6 array is shown in Fig. 1. It consists of 4 sub-assemblies – the bottom cover, a microstrip beamforming network, a grid of metallic cavities and a printed patch layer. The rectangular patch elements are printed on a Rogers's 0.5mm thick substrate with dielectric constant of 3.55 as depicted in Fig. 2. The substrate also forms the radome of the array. The 2.54 mm diameter probe feeding the patch protrudes through the bottom wall of the cavity and connects to a 50-ohm microstrip feed line printed on a 0.5 mm thick substrate with dielectric constant of 2.2, as shown in Fig. 3. The probe section through the substrate together with the outer ring of plated via holes has a 50-ohm line impedance. This results in a stepped probe which facilitates the integration and soldering at the patch and feed line junctions. The computed active match of each element in an array environment is plotted in Fig. 7 at the coax input. Worst case return loss occurs at the band edge and is about -11 dB.

The 1:36 way feed network for the array contains one-section Wilkinson -3dB and -4.77 dB power dividers, as shown in Fig. 5, to provide equal excitations of the elements. The entire feed network has a metallic cover spaced 0.5 mm above the board surface. In addition, metallic side walls are also placed on either side of the transmission lines to prevent overmoding and minimize circuit loss. These side walls are milled into the aluminium cover. The dynamic effects of the top and side walls on the microstrip line impedances are taken into account by using the generalized transverse resonant technique. The line widths are reduced by the proximity of the top and side walls. Connecting the feed network to the exterior and is a MMCX connector as can be seen in Fig. 1.

The computed peak directivity is 21.6 dBi at mid-band. The feed network loss is about 1.3 dB and the mismatch loss is 0.4 dB at the worst case. This gives a mid-band gain of 20.3 dBi and a band edge gain of 19.9 dBi. The active element pattern cuts and the array pattern cuts are plotted in Fig. 8 and 9 respectively. The element patterns out to the -3 dB beamwidths are the same in the principal and diagonal planes. The array co-polar patterns are also symmetric down to -10 dB beamwidths with very low cross-polar levels and rapidly decaying sidelobes.

4. Conclusion

The design of a very low profile array with a high gain and excellent pattern characteristics has been presented. It covers the entire C-band WLAN band.

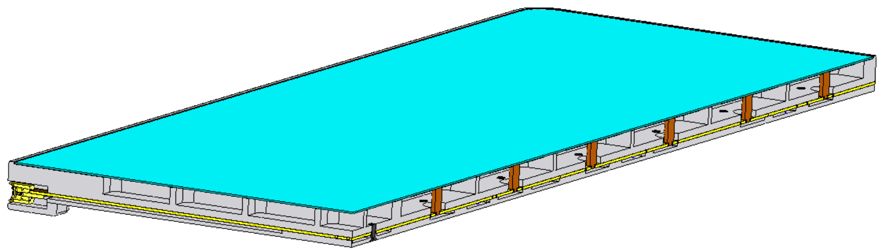


Figure 1: Cut-away View of the 6 x 6 C-Band Array

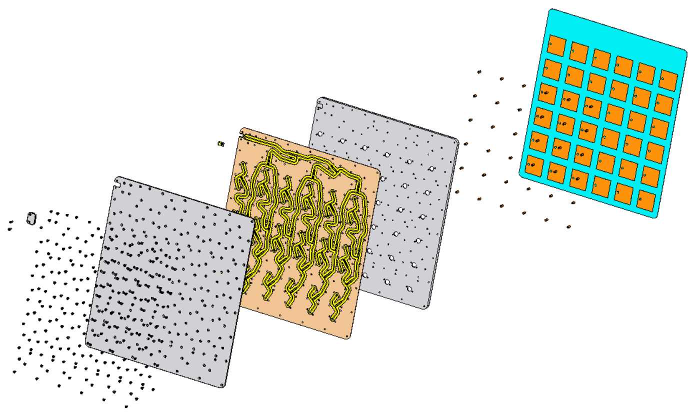


Fig. 2: Interior View of the 6 x 6 C-Band Array

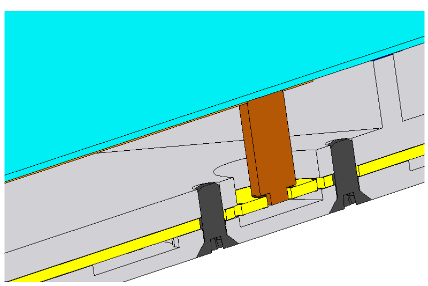
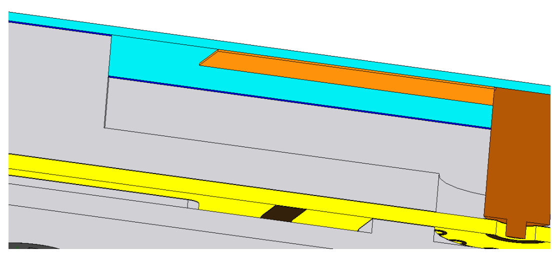


Fig. 3: Probe Feed



Fig, 4: Channelized Feed Line

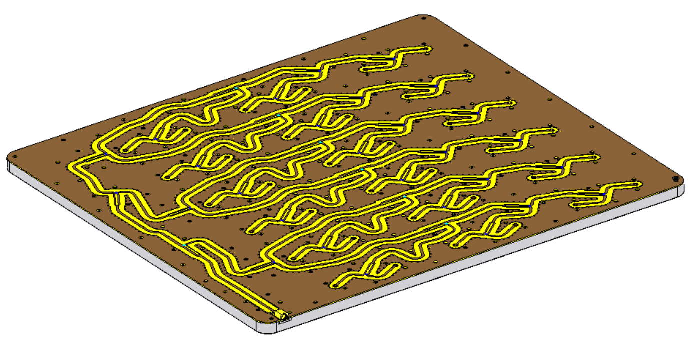


Fig. 5: 1 - 36 Way Feed Network

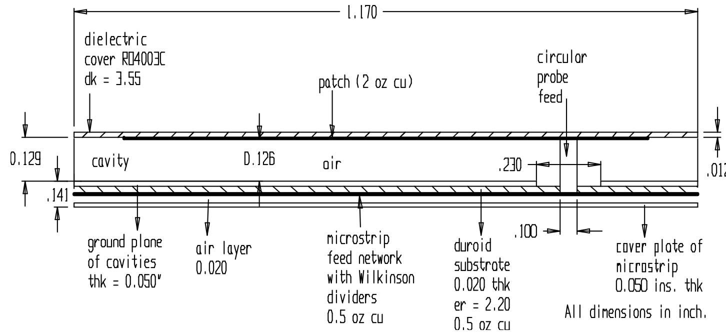


Fig. 6: Side View of the C-Band Array Element

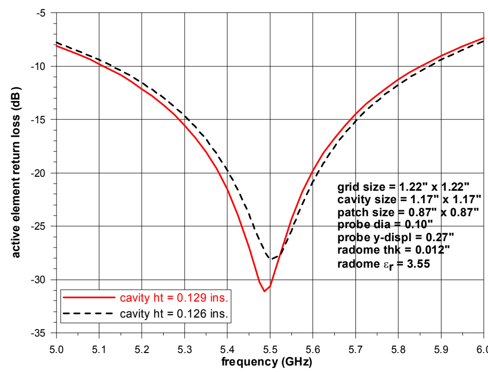


Fig. 7: Active Match

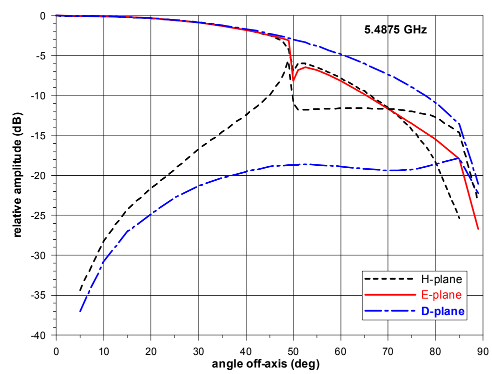


Fig. 8: Active Element Pattern Cuts

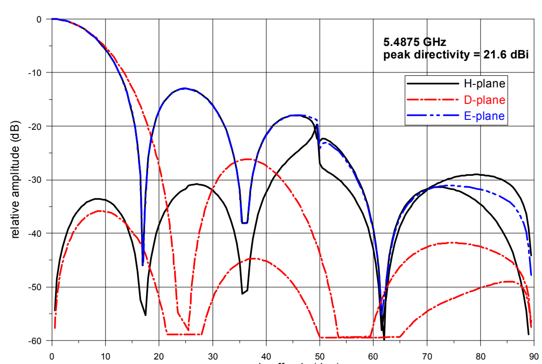


Fig. 9: Co-polar and Cross-polar Array Pattern Cuts