Integrated Antennas for Millimetre-Wave Asset Tracking

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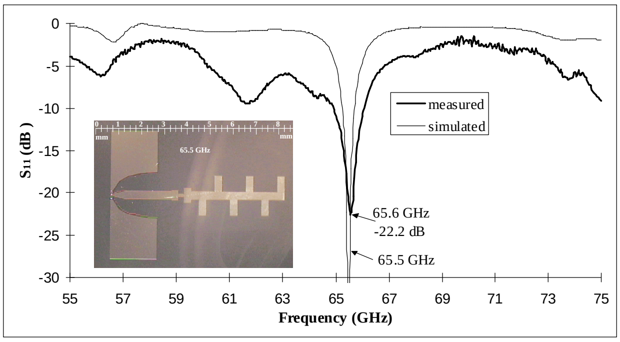
Abstract

A soft board-board millimetre wave subarrayed Van Atta antenna has been designed fabricated and measured for asset tracking applications at 62GHz**.** Soft-board, 254 µm thickness and 2.19 relative permittivity, single and array patch antennas were designed and characterised. The elements and arrays are designed to be connected via microstrip to WR-15 waveguide transitions. Measurements of insertion loss for the transition have been performed and the transition used to allow patch array and subarray absolute gain values to be computed. The performance of the Van Atta Array is also given and peculiarities of its performance at mm-wave frequencies described. The characteristics of a millimetre wave integrated Silicon antenna are discussed also. The frequencies chosen for this work are 62.5 and 65.5 GHz. These are transmit and receive frequencies allocated for broadband Mobile wireless applications [1].

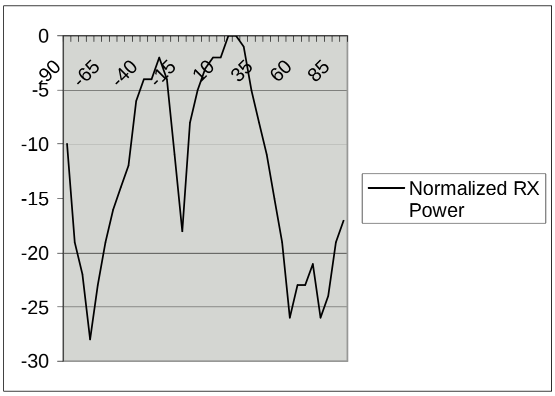
Silicon Antennas

Series silicon antenna arrays were designed using 50 Ω half-wavelength dipoles separated by half-wavelength 50 Ω lines metallized using 1.5µm aluminium on patterned SiO_2, placed on 10 kΩcm Silicon, εr=11.9, Figure 1. The dipole antenna was matched using a λ/4 transformer. Coplanar pads were designed to probe the antenna with 150 µm. The ground pads are connected to a large metallization, 0.1 Ω impedance, in order to act as a ground plane. This type of grounding occupies large area but eliminates the need for thru-hole via fabrication.

Figure 1a shows the measured and simulated reflection loss of the silicon dipole array (series configuration). The measured resonant frequency is 65.6 GHz with -22.2 dB reflection loss compared with 65.5 GHz designed frequency. The measured resonant bandwidth is wider than the simulated bandwidth for both resonant frequencies due to dielectric and metallization losses i.e. reduced Q. After extraction of bondwire and antipodal finline losses, the antenna gain was found to be 8 dBi.



(a) Series Array



(b) Radiation characteristic

Figure 1 Silicon half-wavelength dipole antenna array

The radiation characteristic for this antenna is squinted, this is thought to be due to the close proximity of the waveguide step with respect to the feedline of the antenna, combined with secondary radiation from the pen waveguide face.

Design of Softboard Array

Next a single patch antenna and then a 2X2 softboard microstrip patch array were designed and fabricated. For each patch the input impedance was 90 Ω in order to facilitate matching in the subarray to the 50Ω impedance to be used in the Van Atta array to be described below.

The single patch element return loss response and that of the 2X2 array is illustrated in Figure 2. From Figure 2 it can be seen that the return loss for the 2X2 array is –10dB at 65.1GHz while for the patch it is also –10 dB.

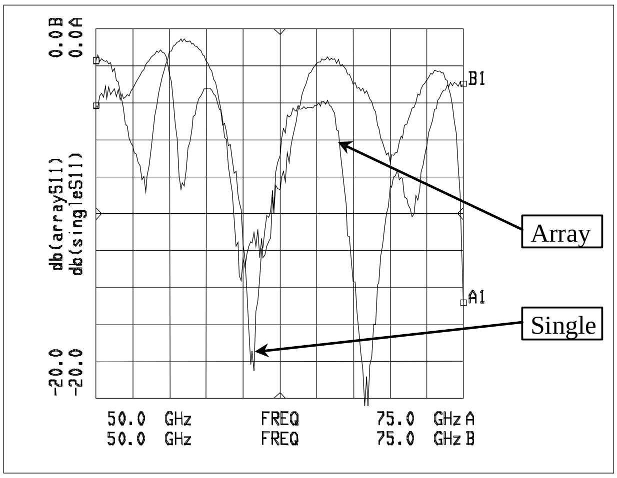
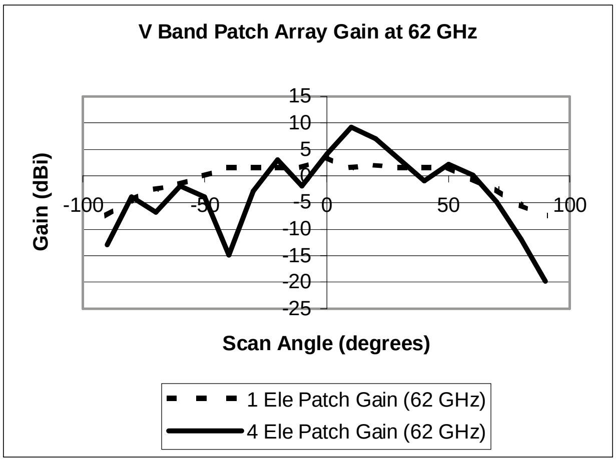
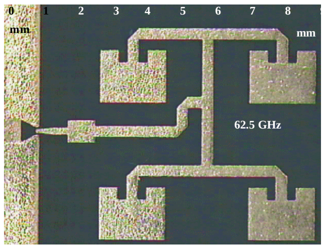


Figure 2 Softboard Microstrip Patch and Array Return Loss

A measured typical radiation pattern is shown in Figure 3 for the patch element and the 2X2 array. The theoretical beam width of a 2×2 planar patch array separated by $\lambda_0/2$ edge to edge is 27º (measured 25º) for $\phi = 0$ with -8.5 dB side lobe level (measured 7dB). the measured pattern for the 2X2 array exhibits 9º squint from broadside which is thought to be due to the proximity of the horizontal feed connection shown in Figure 3(b).
The measured gain for a single 62GHz microstrip patch on Taconic material is 2.4dBi, while the 4 element patch array gives around 9dBi gain. The 65 GHz silicon dipole array gives around 4.5dBi gain. The lower than expected gain of the silicon array is thought to be due to its increased dielectric and metallization losses. A single GaAs patch antenna (840µm X 617µm) designed for use at 65GHz yielded a measured return loss of –9.4dB with 2.6dBi gain. An array of GaAs elements is too expensive in area requirement hence the need for the softboard and Silicon alternatives discussed in this paper.



(a) Far field patterns



(b) physical circuit 2x2 subarray

Figure 3 Softboard radiation patterns

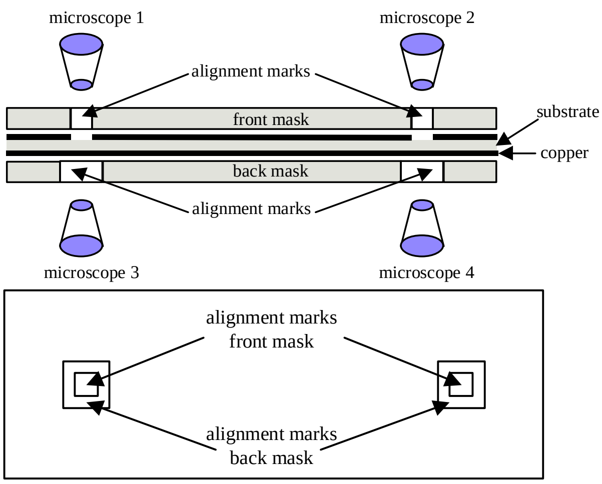
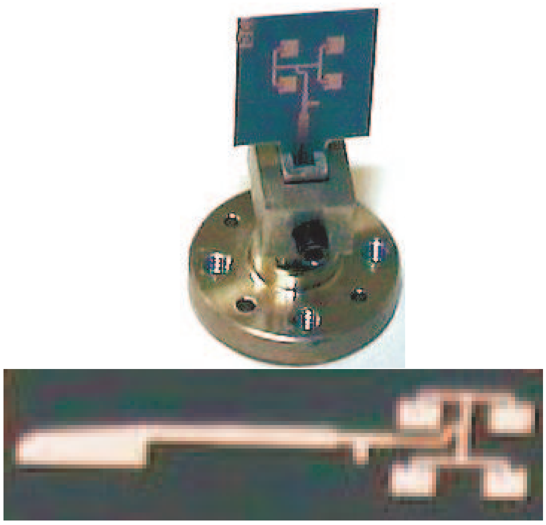


Figure 4 Double Mask Alignment Procedures

Antipodal Measurement Interface

In order to create a stable interface for antenna measurement at mm-wave frequencies we investigated how to construct a WR-15 to microstrip transition with integral antenna attached. To do this we had to develop double sided mask alignment for Silicon and for softboard antenna variants. The procedure using a split optics approach is shown below in Figure 4. The transitions formed by using this assembly method have better than – 15dB return loss and –2.5dB insertion loss at 62 – 65GHz.

In figure 5 we show a typical installation of a microstrip patch subarray connected via the transition to a section of WR-15 waveguide, the antipodal transition is illustrated also.



(a)

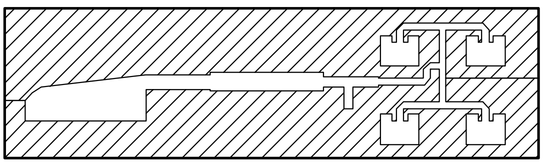
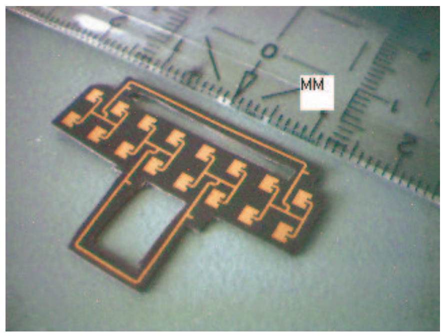


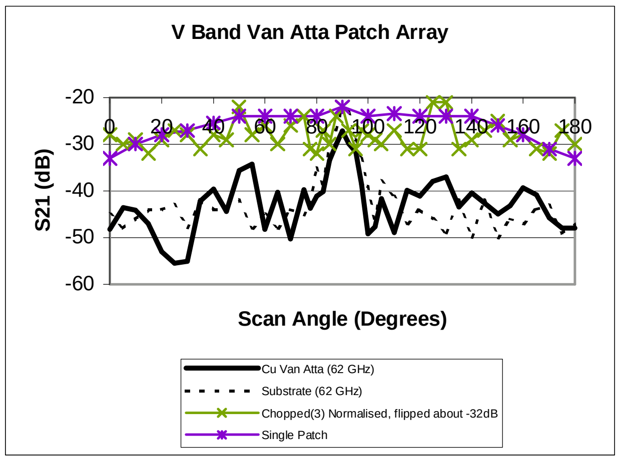
Figure 5 WR-15 to Microstrip Array Transition.

62 GHz Van Atta Array

Using the 2X2 sub-arrays described above a 62GHz Van Atta array [2] was constructed and tested, Figure 6. From Figure 6 it can be seen that reflections of the dielectric material used to form the patch array will mask the arrays performance due to auxiliary reflection [3]. Typically the target gain of the 24mm X 33mm metal backed dielectric plate on which the antenna elements is fabricated is calculated to be about 35dB at 62GHz. This value is greater by 17dB than the theoretical maximum gain of the Van Atta array i.e. 18dBi. Therefore it is essential that as much redundant dielectric is removed from the array face in order to minimise this backscattering mechanism which tend to swamp the desired self-tracking response of the passive Van Atta Array, i.e. the Cu Van Atta response shown in figure 6b, (this undesirable effect can be minimised by using an active self tracking array [4]). When surplus dielectric was removed, figure 6a, the normalised results in figure 6b were obtained. These show that self tracking by the antenna array is actually occurring (with around 5dB ripple caused by residual backscatter from the remaining substrate material). Here it can also be seen that the array is capable of tracking with a similar amplitude profile to that of a single patch antenna but with 15dBi gain, c.f. 2.6 dBi for the single element.



(a) 62GHz VanAtta Array



(b) response

Figure 6 62GHz Van Atta Array

Conclusions

Silicon, GaAs and soft-board antennas have been designed, fabricated and measured for use as radiating elements for V-band millimeter wave wireless asset tracking front ends. It has been shown that it is possible to construct the array to operate to within 0.2% of the design frequency with –10dB return loss. Results on the performance of an mm-wave passive Van Atta array show that auxiliary scattering from the dielectric material on which the radiating elements are constructed play a critical role in its overall success as an asset tracking antenna.

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