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ON-BODY ANTENNA WITH PARASITIC ELEMENTS

MUHAMMAD RAMLEE KAMARUDIN
PETER S. HALL

10.1 INTRODUCTION

An antenna with multi-elements that act together to form an array is required to increase the gain. One example is the well-known Yagi-Uda antenna. Such an antenna is widely used for television communication in which it operates at high frequency (HF), very high frequency (VHF) and ultra high frequency (UHF). It consists of a driven element and a number of parasitic radiators in which currents are induced by mutual coupling. Some applications consider the mutual coupling effect undesirable because it degrades the performance. However, in the parasitic array it is central to the operation. The parasite elements are useful to increase the gain, create a directional beam and enhance the bandwidth impedance of the antenna.

Switched beam arrays can give higher gain than single elements and can be used to improve the performance of small communications base stations and terminals. In addition, Body Area Network (BAN) using communication channels between two body mounted antennas, can also benefit. The path gain of the antennas for two body channels has been established and the optimum antenna type was found to be a monopole antenna for these channels.

In these on-body or other terminal and base station applications, beam switching can be used to increase gain and hence reduce link loss and battery consumption, or to reduce interference or multipath. The disk-loaded monopole antenna has the advantages that the height of the monopole antenna can be reduced significantly whilst still giving approximately the same performance.

Parasite elements can be either reflectors or directors. Normally there is one reflector and many directors. The reflector acts as an inductive element that causes the antenna to radiate more power away from it. Generally the height of reflector is 5% longer than the driven element. In contrast, directors are capacitive elements, which direct the power radiated by the antenna in their direction. They are normally 5% shorter than the driven element. The directors support induced currents that create a wave travelling along the array.

An alternative approach based on the basic principle of a Yagi-Uda array that uses one driven element encircled by a number of parasite elements can be also applied to monopole antenna arrays, dipole antenna array and microstrip patch antenna arrays. By placing the parasite elements, the input impedance and the radiation characteristics of the antenna have been modified due to the mutual coupling between the driven and parasite elements. For instance, in the monopole and patch array, the parasitic element becomes a reflector when shorted to the ground plane, and when not shorted, acts as a director. In other word, the termination impedances of parasite elements are switchable to change the currents flowing. This is different to the conventional Yagi, in which the reflector and directors are determined by their length. This configuration is therefore useful for switched beam control because the actions of the changes in currents of each parasites and their combined effect on the driven element can give rise to change in radiation pattern.

Examples of coaxial-fed monopole antenna arrays, based on the Yagi concept, that have been published recently are the switched parasitic monopole antenna arrays, electrically steerable passive array radiators (ESPAR) and dielectric embedded ESPAR antenna arrays for wireless communications. It is clear that the beam of the antenna can be switched by isolating one of the parasitic elements from the ground plane whilst, the other elements are shorted to the ground. Meanwhile, by changing the control voltage to the parasite elements, it is possible to form the main beam radiation in the direction of the director.

10.2 COAXIAL-FED MONOPOLE ARRAY ANTENNA DESIGN

Figure 10.1 shows the switched top loaded monopole array, designed for this project, consisting of five elements on a small thin circular ground plane, fed by a coaxial cable. The antenna is designed for the 2.45GHz ISM band. Switching is simulated by open circuiting one of the elements. From the figure, it can be seen that the driven element (1) is located at the centre of the ground plane and encircled by four equidistant disk-loaded parasitic elements (2-5). The disks all have the same height, which will enable printed circuit production to be used to reduce production cost.

The driven and parasitic elements consist of a disk above a cylindrical rod monopole. The rods in the driven element and parasites are of different diameter. The disks used for parasitic elements are also made about 5% smaller in radius compared to the driven disk. The antenna parameters that have been studied were the driven disk radius, R_d and parasite disk radius, R_p (from 13mm to 15mm), the ground plane radius, R_g (from 30mm to 50mm), the height of elements, h (from 9mm to 14mm), the driven cylindrical rod radius, R_{cd} (from 2.5mm to 5mm) and the parasite cylindrical rod radius, R_{cp} (from 1mm to 3mm). The aims of the optimized antenna dimensions were to obtain good matching at the feeding point and the gain improvement. The final dimensions are given in Table 10.1.

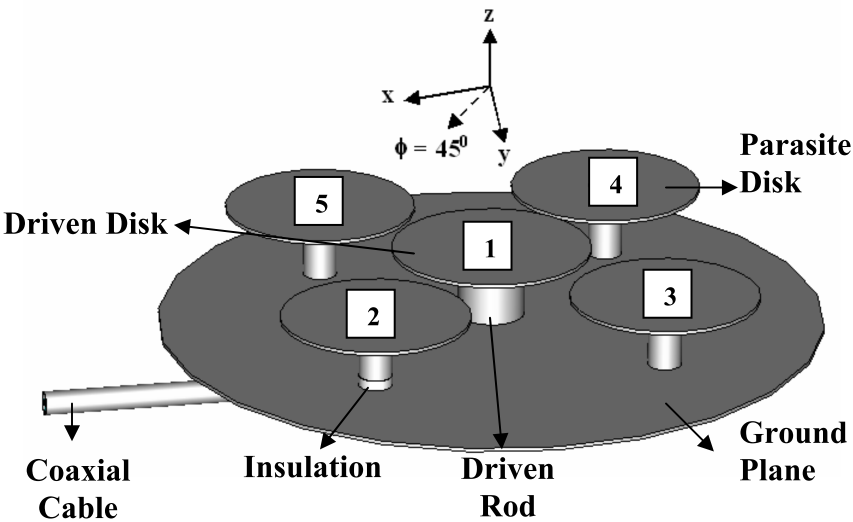


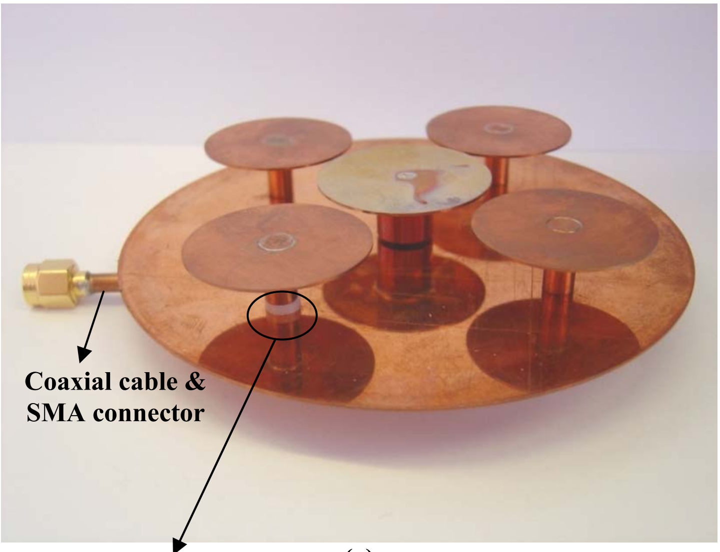
Figure 10.1 Disk-loaded monopole array antenna (No. 1 = driven element, No. 2-No. 5 = parasite elements)

Table 10.1 Dimensions of a disk-loaded monopole array antenna

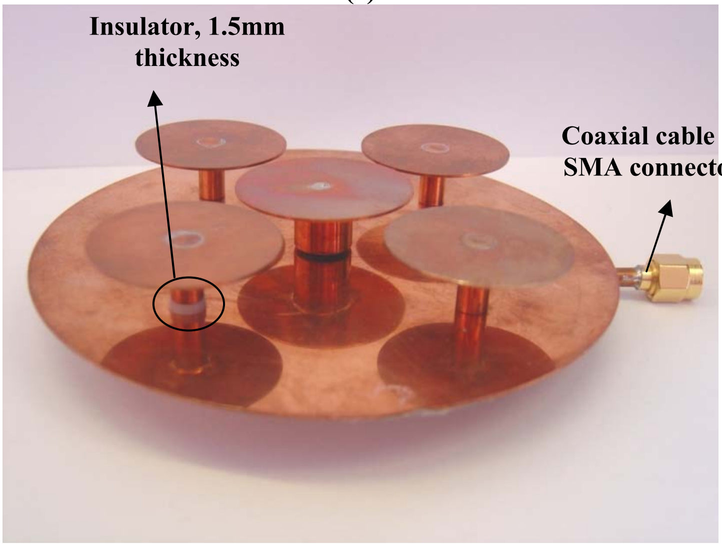
Components	**Unit (mm)**
Ground plane radius, R_g	50.00
Driven disk radius, R_d	15.00
Parasite disk radius, R_p	14.25
Height of elements, *h*	11.00
Driven cylindrical rod radius, R_{cd}	5.00
Parasite cylindrical rod radius, R_{cp}	2.53
Disk and ground plane thickness, *t*	0.55

The antenna matching is mainly controlled by the diameter of the driven element rod. The gain of the antenna is related to the dimensions of the parasitic elements including disk size, rod radius and their distance to the driven element. The distance between the centre of the driven element to the centre of the parasites has been chosen to be about λ/4 (31mm) which is in line with traditional Yagi antenna spacing.

There are two variations of the array that have been made as shown in Figure 10.2. The reason behind this is to investigate



(a)



(b)

Figure 10.2 Photographs of the antenna with one of the parasite element is lifted 1.5mm using insulator while the remaining are shorted to ground: Frequency 2.45GHz; (a) Antenna with same configuration as in Figure 2, and (b) Antenna with the opposite configuration

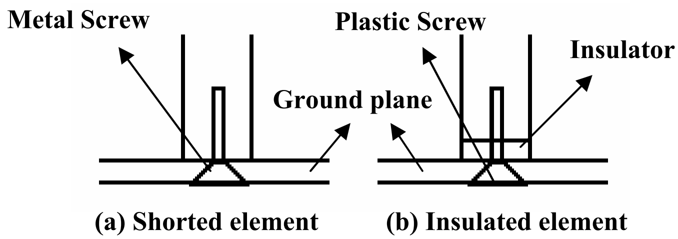


Figure 10.3 The technique of shorted and insulated element

the beam switching when changing the parasite state. Figure 10.2 (a) shows three of the parasites are screwed to the ground plane as in Figure 10.3 (a). These act as reflectors, while the remaining parasite (director) is elevated by about 1.5mm and is bolted to the ground plane using a plastic screw and insulator, Figure 10.3 (b). In Figure 10.2 (b), the director is in the opposite location to the antenna in Figure 10.2 (a).

10.3 RESULTS

Figure 10.4 shows the simulated and measured results for the input return loss, S_{11}, for the antenna shown in Figure 10.2 (a). From the figure, it can be observed that good agreement between the simulated and measured results has been achieved. However, it can be observed that the measured result produced more impedance bandwidth than the simulated result. This may be due to imperfection occurred during the antenna construction process which may modify the impedance of the antenna. Nevertheless, the fractional bandwidth for reflection coefficient below –10dB is about 24% (from about 2.2GHz to 2.8GHz) and covers the 2.45GHz ISM band.

Figure 10.5 illustrates the normalized antenna radiation patterns for both E and H planes for the antenna in Figure 10.2 (a). It can be seen that for the H-plane pattern, the beam has been steered to direction A, that is $\phi = 45°$, which is in the direction of

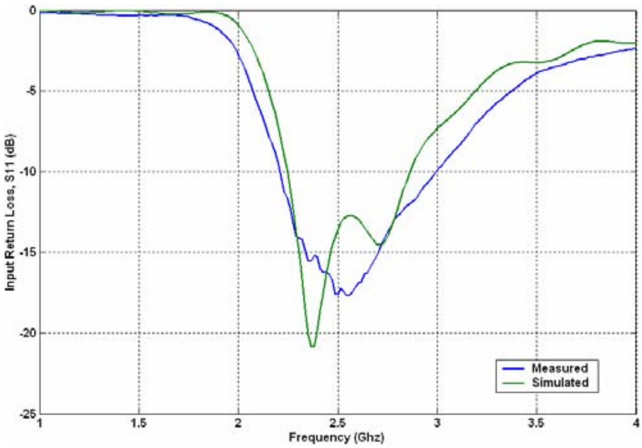
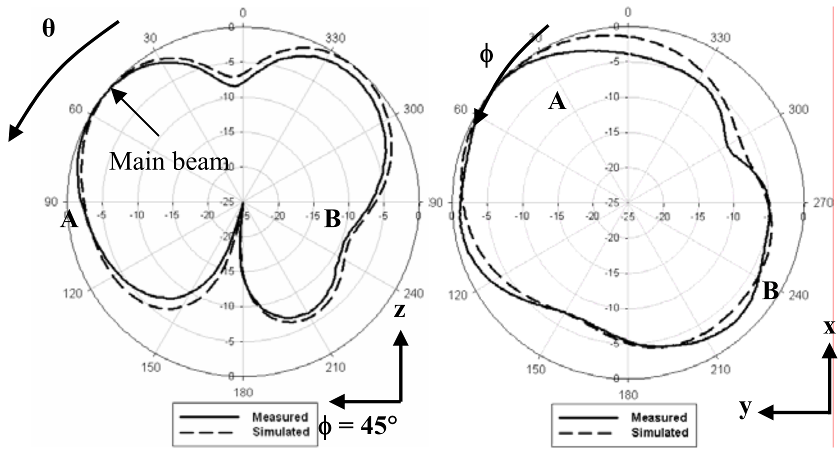


Figure 10.4 Input return loss against frequency for the antenna in Figure 10.2 (a)

the open circuited element, as expected. However as shown in Figure 10.5 (a) the beam has also been tilted upwards to θ = 50° above the plane in the open circuited element direction. It also can be noticed that a peak also exists at θ = 315° in the direction of the short circuited element opposite the open circuited element in the parasitic ring. This is clearly seen in the both simulated and measured results.

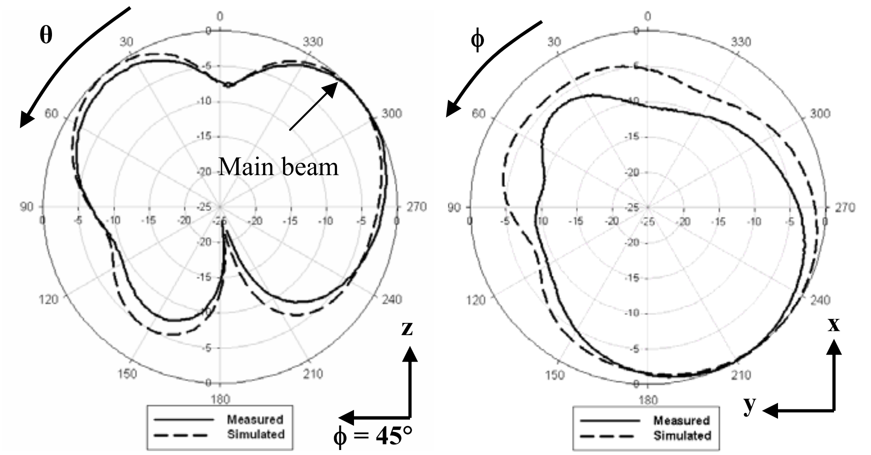
The predicted gains at angle θ = 50° and θ = 315° are 4.40dBi and 4.38dBi respectively. The antenna gives 5.10dBi of measured gain which is more than three times greater than the 1.50dBi of the single disk-loaded antenna. In addition, this antenna is more compact and can be made with printed circuit construction, which is particularly useful for the on-body communications applications, where the extra gain over a single disk monopole can be used to extend the battery life of portable body mounted equipment or to overcome multipath fading.



(a) Normalized E-plane pattern at ϕ = 45° **(b) Normalized H-plane pattern**

Figure 10.5 The radiation patterns of the antenna in Figure 10.2 (a). (A and B respectively in both plots are same direction). Frequency = 2.45GHz

The antenna beam radiation can be switched to other directions by changing the position of the open circuiting element. To prove this, the antenna configuration as shown in Figure 10.2 (b) was measured and simulated. Figure 10.6 shows the patterns of the antenna. It can be seen that, the antenna pattern has been altered, with a peak in the $\phi = 225°$ and $\theta = 315°$ direction. Again, the two peaks exist at $\theta = 315°$ and $\theta = 50°$ in the $\phi = 45°$ plane, and elevated above the ground plane. Simulations show that the main beam is tilted in elevation due to the finite ground plane. The researchers have demonstrated that the antenna pattern can be brought down to the horizontal plane by utilising the ground skirting attached to the ground plane. The results for the two antennas clearly demonstrate the potential of this array for a switched beam application.



(a) Normalized E-plane pattern at ϕ = 45°

(b) Normalized H-plane pattern

Figure 10.6 Radiation patterns for the antenna in Figure 10.2 (b). Frequency = 2.45GHz

10.4 CONCLUSION

A switched disk-loaded monopole antenna array with parasitic elements for BAN application has been proposed. The array was fed by a coaxial cable and had a 100mm diameter ground plane and 11mm height. It produces good input return loss and covers the frequency range from 2.2GHz to 2.8GHz for S_{11} below –10dB. The antenna peak radiation was in the direction of the open circuited element and was elevated above the ground plane at about 50°. The antenna had a measured gain of 5.10dBi, which is more than three times the gain of a single top disk-loaded antenna.

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