Testing Of Detector for Easing Of Multipath for A GNSS Receiver Using a Micro strip Array Antenna

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Abstract: A novel design of four-element gap-coupled slot rectangular microstrip array antenna is presented for broadband operation. The elements of antenna are fed using aperture coupled technique. From the experimental results it is seen that the antenna operates at single band of frequencies and shows broadside radiation characteristics. The overall impedance bandwidth is found to be 26.72 %, which is 1.114 times more than that of Global Navigation Satellite System array antenna (GNSS). This shows the effect of slots in enhancing impedance bandwidth of GNSSMA. The slots in GNSSMA also improve the antenna input impedance and increase the gain by 20.8% when compared to GNSS. Details of antenna designs are described and experimental results are discussed.

Keywords: *Slot antenna, Aperture coupling, Array antenna, Microstrip antenna, Wideband antenna, Rectangular antenna*

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1 Introduction

The microstrip antennas are very popular because of their low profile, conformal, low cost and ease in fabrication. They can be deployed for a wide variety of applications in microwave communication. However, microstrip antennas and their arrays inherently have narrow impedance bandwidth, which is one of their main drawbacks. Number of studies has been conducted on enhancement of impedance bandwidth of rectangular microstrip array antenna[1,2]. In the year 2004, Chakraborthy *et al*.[3] have presented 4 × 4 rectangular aperture-coupled microstrip array antenna. They achieved nearly 11% of impedance bandwidth. But the proposed antenna is relatively compact in its size as it uses only four radiating and two parasitic elements. The obtained impedance bandwidth is 2.43 times more than found earlier[3].

The antennas are sketched by using computer software Auto-CAD 2002 and fabricated on commonly available glass epoxy substrate material *S*1 of thickness h = 1.66 mm and permittivity εr = 4.2. The elements of four-element gap-coupled rectangular microstrip array antenna (GNSS) and four- element gap-coupled slot rectangular microstrip array antenna (GNSS DESIGN) are fed by using aperture-coupled technique. The dimension of slot placed at the center of radiating elements in the GNSS is

taken in terms of λo, where λo is free space wavelength in cm. The length *Ls* and width *Ws* of slot is taken as λo/4 and λo/16, respectively. This slot is considered as a wide slot, as its width is comparable to its length. The wide slot is selected because it is more effective in enhancing impedance bandwidth when compared to narrow slot[4]. The coupling slots are placed in the ground plane at the center with respect to the radiating elements, where the magnetic field of the radiating elements is maximum[3]. This is done to enhance coupling between the magnetic field of the radiating elements and the equivalent magnetic current near the slot.

2 Description of antenna geometry

Figure 1 shows the geometry of GNSS. The radiating and parasitic elements are etched on top surface of substrate *S*1. The corporate feed arrangement is etched on the bottom surface of the substrate *S*2 having the same dielectric constant εr and thickness h as that of *S*1. The corporate feed arrangement consists of matching transformers, power dividers and microstrip bends (m) used for better impedance matching to the coupling slots. The coupling slots are placed on the top surface, which is the ground plane of the substrate *S*2 exactly at the tip of 50-Ω microstrip feed line of corporate feed arrangement. The radiating elements on the top surface of the substrate *S*1 is energized through coupling slots placed on the top surface of the substrate *S*2. The substrate *S*2 is placed below the substrate *S*1. This forms the aperture-coupled feeding technique[5].

The parasitic element is placed between the radiating elements along their widths, which forms the gap coupling. The distance between the parasitic and radiating element is taken[6] as S = 0.025 λg, where λg is the operating wavelength[4] in cm. The length of the parasitic element is adjusted in order to satisfy the distance condition 3λo/4 between the two radiating elements[7] from their center. Usually the spacing between the two radiating elements is kept at a distance of λo/2 for minimum side lobes. But in this case, it is difficult to accommodate corporate feed arrangement between the two radiating elements when the distance is λo/2. If this distance is increased, accordingly the feed line has to be extended, which increases radiation losses in the feed line. Hence, corporate feed arrangement is kept as small as possible by selecting spacing between two radiating elements to be 3λo/4.

Figure 2 shows the geometry of GNSS DESIGN. The elements of Fig. 2 replace those of Fig. 1(a). In this geometry the slot is inserted at the center of radiating elements parallel to their width. The dimensions of radiating, parasitic, slot and corporate feed line network are as presented in Table 1.

3 Experimental results

The impedance bandwidth over return loss less than –10 dB for the proposed antennas is measured for X-band frequencies. The measurement is taken on Vector Network Analyzer. The variation of return loss versus frequency of GNSS and GNSS DESIGN is shown in Fig. 3. From this figure it is seen that the GNSS resonates for two bands of frequencies. From this graph the impedance bandwidth is determined by using the equation

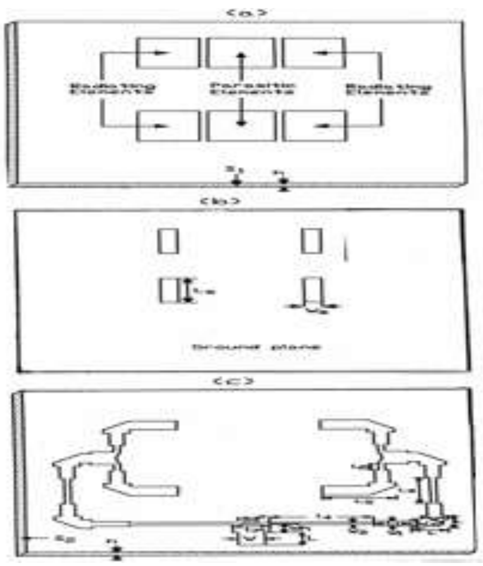

Fig. 1—Designed geometry of GNSS [(a) Array elements, (b) Slot array on ground plane and (c) Feed network]

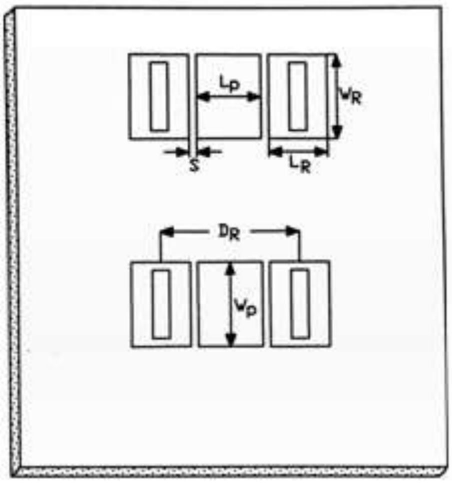

Fig. 2—Designed geometry of GNSS DESIGN

Table 1—Various dimensions of radiating and parasitic elements, slot and corporate feed line network

(a) Patch dimensions	Value, cm
Length of the radiating element (L_R)	0.71
Width of the radiating element (W_R)	0.99
Length of slot (L_s)	0.80
Width of Slot (W_s)	0.20
Length of the parasitic element (L_P)	0.80
Width of parasitic element (W_P)	0.99
Distance between the radiating & parasitic element (S)	0.04
Distance between two radiating elements (D_R)	1.61
Operating wave length (λ_g)	1.64
Free space wavelength (λ_o)	3.19

(b) Network dimensions	Value, cm
Length of 50 Ω line (L)	0.41
Width of 50 Ω line (W)	0.30
Length of 50 Ω matching transformer (L_M)	0.41
Width of 50 Ω matching transformer (W_M)	0.30
Length of 70Ω line (L_1)	0.41
Width of 70 Ω line (W_1)	0.16

radiating elements[6]. The maximum return loss achieved at (BW1) and (BW2) is – 26 dB and – 30 dB, respectively. Further from this figure it is seen that the GNSS DESIGN operates at one band of frequency and gives an impedance bandwidth (BW3) of 26.72%, i.e. 2.64 GHz, which is 1.114 times more than that of GNSS and with a greater return loss of up to – 33

$$BW = \frac{(f_2 - f_1)}{f_c} \times 100\,\%$$

dB. This enhancement of impedance bandwidth is due to the combined effect of radiating and parasitic elements as explained for GNSS, which acts as a primary resonator, and the slot in the radiating patches

where, f_2 and f_1 are the higher and lower cut-off frequencies of the band respectively, when its return loss reaches − 10 dB and f_c is the centre frequency of this band.

The experimental results show that the antenna operates at two wide bands of frequencies and the total impedance bandwidth (BW1 + BW2) is found to be 23.99%, i.e. 2.5 GHz. This impedance bandwidth is due to the combined resonance effect of parasitic elements and the coupling slots that couple energy from the feed line to the radiating elements. The coupling slot can be either resonant or non-resonant. If it is resonant, the current along the edges of the slot introduces an additional resonance[8], which adds to the fundamental resonance of radiating element, causing enhancement in the impedance bandwidth.

Hence, from Fig. 3 it is seen that the enhancement in impedance bandwidth at (BW1) and (BW2) is due to resonance of radiating elements through coupling slots and resonance of parasitic elements near to the acts as secondary resonator[8-10]. The combined effect of these resonances causes merging of bandwidths BW1 and BW2 and hence gives only one bandwidth BW3, which is as shown in Fig. 3.

In order to calculate the gain, the power received (*P*s) by the pyramidal horn antenna and the power received (*P*t) by GNSS and GNSS DESIGN are measured independently at their resonant frequencies. With the help of these experimental data the gain of antenna under test (*G*T) in dB is calculated using the formula

$$(GT)\text{dB} = (Gs)\text{dB} + 10 \log (Pt/Ps)$$

where, *Gs* is the gain of pyramidal horn antenna. From this the gain of GNSS and GNSS DESIGN is found to be – 13.11 dB and – 10.38 dB, respectively. It is evident that the use of slots in the radiating elements in GNSS DESIGN increases the gain by 20.8%.

The co-polar and cross-polar H- and E-plane radiation patterns of GNSS and GNSS DESIGN are measured in their operating band. The typical radiation patterns of these antennas are shown in Fig. 4[(a)-(d)]. From Figs 4(a) and (b), it is seen that H-plane radiation patterns are broad sided with side lobes and cross-polar levels are below – 5 dB, indicating linear polarization of radiation[11] and pattern is uniform from their center axis. From Figs 4(c) and (d), it is found that the E-plane co-polar radiation patterns are having minimum side lobes and gives better broadside radiation pattern and the cross-polar levels are below – 10 dB. This shows the merits of E-plane co-polar and cross-polar radiation patterns when compared to H-plane co-polar and cross-polar radiation patterns. Further from Figs 4(a) and (b), it is seen that the GNSS DESIGN gives wider beam-width as that of GNSS. The wider beam-width is because of insertion of slots in the radiating patches of GNSS DESIGN. However the GNSS DESIGN resonates with a greater return loss and hence gives more gain than that of GNSS, which is evident from Fig. 3. It is also observed that the input impedance of GNSS DESIGN is well matched in the operating band of frequencies.

4 Conclusion

The present study shows that the impedance bandwidth of GNSS DESIGN can be enhanced significantly by adding optimum slots in the radiating elements. The maximum impedance bandwidth of 26.72% is achieved in case of GNSS DESIGN at X-band frequencies (8-12 GHz). This impedance bandwidth is 1.114 times more than that of GNSS and 2.43 times more than the earlier result[3] without changing broadside-radiating characteristics. This shows the effect of parasitic elements and slots for enhancing impedance bandwidth by using aperture-coupled feeding. The proposed method also improves the input impedance of antenna and increases the gain by 20.8% when compared to GNSS. Hence, these compact, wide band antennas are attractive for present-day scientific and industrial application in fields like mobile computing and communication[3].

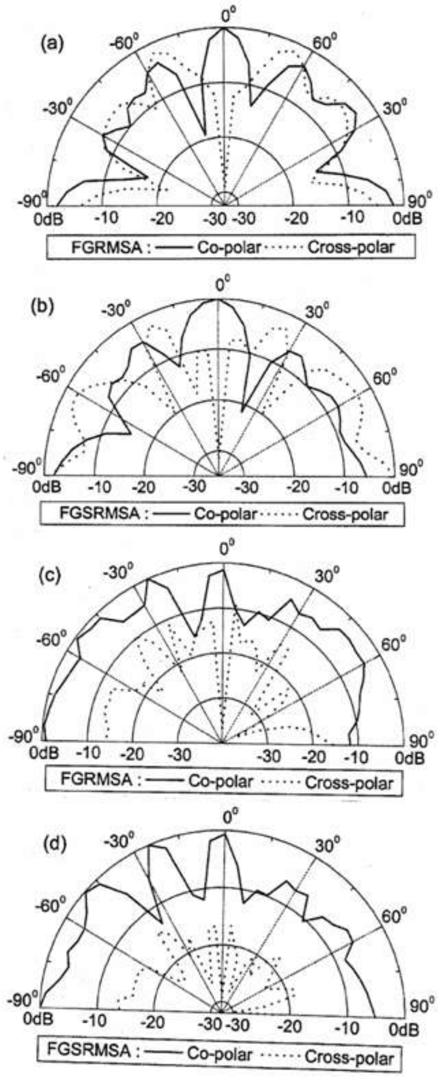

Fig. 4—Variation of relative power versus azimuth angle of (a) GNSS in H-Plane, (b) GNSS DESIGN in H-Plane, (c) GNSS in E-Plane and (d) GNSS DESIGN in E-Plane

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