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Department of Electrical and Computer Engineering

6-2003

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Abstract: Excellent efficiency of a linearly polarized microstrip array in Ku-band is achieved by having proper impedance matching throughout the array and by properly using the corporate and series fed by microstrip transmission lines. The cavity-backed microstrip patch is used to obtain relatively wide bandwidth. The auto-tracking Ku-band antenna in the azimuth direction has developed with a very low profile for vehicle's rooftop mounting, as well as, a low manufacturing cost. The main beam of array is tilted 15^0 away from the broadside direction to provide optimum coverage for Korea satellite III.

1. Introduction

During the earlier years, the adoption of the microstrip antenna in Ku-band has not been as rapid, primarily due to the costs of antenna's substrate material, design, and manufacturing processes when compared to parabolic reflectors. As the cost to develop and manufacture the microstrip antenna has been dropped significantly, microstrip array antenna is now being actively considered for many applications where its thin profile and light weight are important considerations. The mobile satellite system is one of the most prominent communication systems that will utilize it. The antenna for the ground terminal of the satellite communication requires a satellite tracking capability to keep its beam pointed at the satellite while the vehicle is moving about. In this work, the microstrip array antenna has been developed for the Korea Satellite III. The elevation angle of 15^0 is steered electrically rather than mechanically for a low-profile microstrip antenna. The beam is scanned in the azimuth plane by mechanical tracking system. A low-profile antenna with a vertically polarized fan beam (approximately 5^0 x 15^0) is need for the Korea Satellite III in Ku-band. The main beam of the antenna is required to fixed at 15^0 away from the broadside direction. The available physical area for the antenna is 250mm x 82mm. The feed network is one of the most troublesome aspects of a microstrip antenna. At the high frequency (Ku- or Ka-band), the primary factor of the microstrip array efficiency is the loss of the feed transmission lines [1], [2]. The simplest form of feed system for such a relatively large array is series feed. Because the feed arrangement is compact, the space usage can be improved, and the line losses associated with this type of array are lower than those of a corporate-fed type. . Since input power to the antenna should come from one end of the array, the main limitation in series-fed arrays is the large variation of the input impedance and beam-pointing direction over a band of frequencies. In the corporate feed, the advantages include design simplicity, flexible choice of element spacing, and broader bandwidth since the antenna element are fed by 1: n power divider with the equal line lengths from the feed point to each element. However, the length of feed lines for large arrays results in high insertion loss at higher frequencies. To obtain higher efficiency and avoid the variation of beam-pointing direction, the optimal combination of corporate-and series-feed techniques is used in this work [3]. The proposed array as shown in Figure 1, has eleven stages of the parallel feed. Good gain

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bandwidth performance has been achieved with the cavity-backed square microstrip patch element as shown in Figure 2.

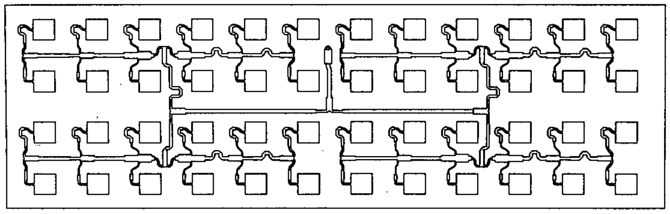


Figure 1. Microstrip array antenna with corporate and series-feeds

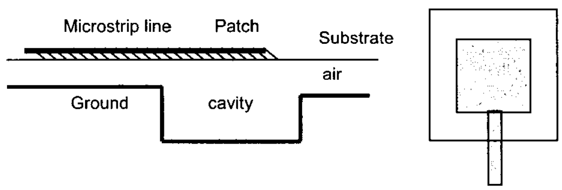


Figure 2. The Geometry of the cavity-backed single patch element

2. Design of the Array

The array, as shown in Figure 1, consists of 4- subarrays. Each subarray has 12 identical cavity-back square microstrip patches. The array is designed to resonate at 12.35GHz. The substrate used is air (ε_r=1, height=1mm) and Rogers Corporation, RO4003(ε_r=3.38, height=0.2mm). The element spacing of the cavity-backed microstrip patch is $0.8\lambda_0$. To obtain the required bandwidth of the element, the total height of the cavity -backed microstrip patch element is 3mm. The height of the microstrip line is 1mm to reduce the radiation leakage from the microstrip line. The subarray, as shown in Figure 1, is interconnected 12 elements by three series-feeds and two parallel-feeds. The series-feed is designed as short as possible to reduce the disadvantage and preserve the advantage of the series-feed. All elements are designed to have uniform power distribution for high gain. To achieve such a power division, the impedance of the line is controlled as shown in Figure 3. The impedance matching is considered at every junction on the transmission lines.. To fix the main beam 15^0 away from the broadside direction, the feed phase of each patch layer from bottom to top direction in Figure 1 is 0^0, 77.4^0, 154.8^0, and 232.2^0, respectively. The performance of the proposed array is fairly agrees with that of calculated.

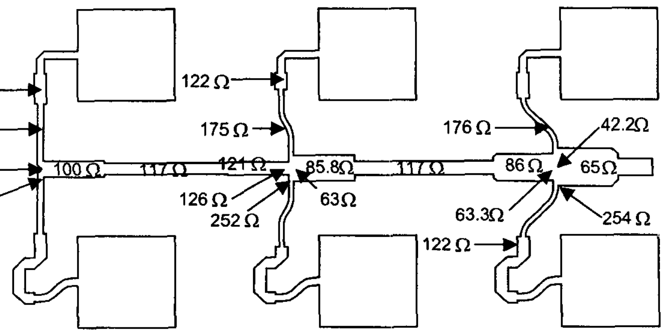
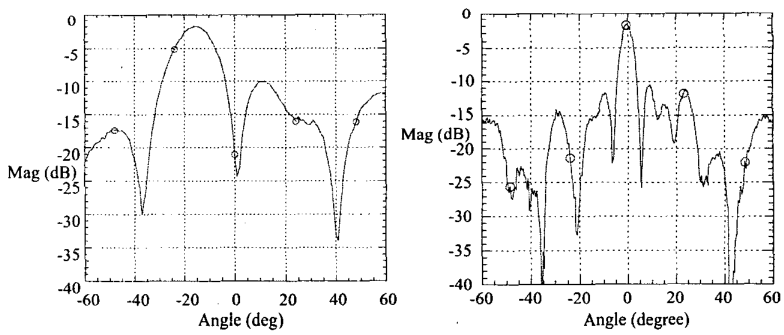


Figure 3. Impedance transformations of a half-subarray section shown in Figure 1



(a) (b)

Figure 4. Measured principal-plane radiation patterns: (a) E-plane, (b) H-plane

3. Array Performance

The measured two principal-plane patterns are presented in Figure 4. The half-power beamwidth in E-plane (Fig. 4(a)) and H-plane (Fig. 4(b)) is about 15^0 and 5^0, respectively. The main beam is directed 15^0 away from the broadside direction as shown in Figure 4(a). In general, the reflected wave is added at junctions in the parallel feed. However, the input phase differences for 15^0 beam tilting result in decreasing the reflected wave at some of junctions [4]. Figure 5 shows the measured input return loss measured at the input port. The loss due to the titled beam is small ($\cos 15^0 = 0.9659$). Table 1 shows the gain, the beamwidth, and the direction of main beam as frequency changes. At the center frequency (12.5GHz) the measured gain is 23.8dBi, while the calculated directivity is 24.44dBi. The return loss of the input port is 20dB. The loss due to microstrip transmission feed in the array is only 0.59dB (87.4% efficiency). Total efficiency is 83.3%. The good antenna efficiency mainly comes from the adequate combination of corporate and series-feed.

Table 1. The gain, beamwidth, and beam direction as frequency changes

Frequency (GHz)	Gain (dBi)	E-plane Beam peak angle	E-plane Half power beam width	H-plane Beam peak angle	H-plane Half power beam width
11.7	22.6	14.5^0	15.4^0	-0.5^0	5.15^0
12	22.9	15^0	15.7^0	-0.5^0	5.11^0
12.2	23.5	15^0	15.3^0	0^0	5.5^0
12.5	23.8	15^0	15^0	0^0	5.1^0
12.7	23.1	15.5^0	14.3^0	0^0	4.5^0

4. Conclusion

Adopting the combined corporate and series feeds, the high efficiency and relatively wide bandwidth microstrip array in Ku-band is developed and manufactured for vehicle mounting application. A low profile and manufacturing cost are also achieved. The elevation angle of beam is controlled electrically rather than mechanically for a low profile of antenna array. The beam is scanned in the azimuth plane by mechanical tracking system rather than the phased array system with phasor shifters to minimize the antenna cost.

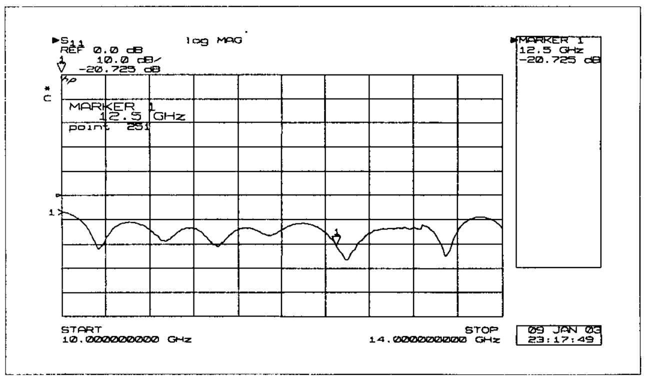


Figure 5. Input return loss versus frequency

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