Low-cost steerable antenna for satellite applications

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Abstract. This paper discussed the design of phased array microstrip antenna which has been developed to serve the ground stations of Non geostationary satellites, the antenna array consists of 5*5 elements, the antenna operates in Ka frequency band, the gain reaches 14 dB with steerable beam which can trace the MEO (Medium Earth Orbit) satellites alongside it’s visible orbit around the earth, the electronic control of the steerable beam make it possible to use one antenna to trace the MEO and LEO (Low Earth Orbit) satellites series for communication services instead of two mechanical movable antennas, the dimension of each element in the array is (4.6mm * 2.6mm) and the total size of the array antenna, substrate dimensions, is (30mm * 28mm) which gives the antenna the advantage of small size, low cost, easy to fabricate and also fast and easy to trace the movement of satellites around the earth.

Key Words: Ka-Band, Microstrip array, satellite, Steerable beam

1. Introduction
The huge increase of satellite services like communications, earth exploration and internet caused that many engineers and researchers made a great effort in using the inclined orbit satellites for broadband services like internet and communication so to guarantee the continuity of connection with the inclined orbit satellite we need many satellites in the same orbit to be visible at least one of the series at any time [1].

According to that the ground stations also need to be movable to trace the satellite in orbit[2] and in some cases customers need two movable parabolic antennas[3] to ensure the connectivity which increase the cost and complexity of the antenna.

Our research focused on the design of microstrip phased array antenna with the ability of beam steering to trace the satellite very fast simply by change amplitude and phase of some feeders and very cheap comparing with traditional parabolic antennas[4].

The designed antenna is working in the frequency range of 27-28.8 GHz which uses for METEOROLOGICAL AIDS [5] services according to ITU-RR [6]. It consists of 25-elements of patch radiators with coaxial-probe feeds. The spacing between the patch antenna elements is 5.8 mm in Y-direction and 8.2 mm in X-direction. all simulations done by using CST software [7].
2. Single patch antenna

The antenna consists of a single layer with substrate from cheap FR-4 and full ground. The schematic of the single patch antenna fed by coaxial probe is shown in Fig. 1, and the single patch antenna dimensions are given in Table 1.

| Ws  | Ls  | Wp | Lp | Wf |
|-----|-----|----|----|----|
| 30 mm | 28 mm | 6.4 mm | 7.2 mm | 0.8 mm |

The results of calculated return loss for different patch widths (Wp) are shown in Fig. 2. We can notice that the center frequency increased as the increasing of patch width. We optimized the patch width as 4.65 to get the lowest return loss.
3. Array antenna design

The array antenna is designed from 25 elements the spacing between each element is 5.8 mm in Y-direction and 8.2 mm in X-direction with separate feeding port for each element as shown in fig3

As shown in figure-4 we can notice that with some fine tuning in the spacing between elements we can shift the transmission band of the antenna to fit our needs,

In order to increase bandwidth of the antenna we choose the 8.2mm spacing between each element in X-direction which results maximum bandwidth and lowest return loss.
The gain of the 5*5 array antenna reaches 14dBi with the ability to point the main lobe direction by changing the phase shift between the feeders of elements according to [eq-1] described below, the half power beam width is 21º in Y-direction and 12 º in X-direction.

\[
\Delta \delta (\theta_0) = -K \cdot d \cdot \sin (\theta_0)
\]

\(K = 2 \times \frac{\pi}{\gamma}\)

\(\gamma\) : wave length.
d: spacing between array elements.
θ₀ : phase shift between the adjacent antenna elements

Table 2 shows the needed phase shift between the array elements to get the main lobe gain at different angles.

Table 2: control steerable beam using different phase shifts

| Beam angle (degree) | 5    | 10   | 15   | 20   | 25   | 30   | 35   | 40   |
|---------------------|------|------|------|------|------|------|------|------|
| phase shift (degree)| -15.3| -30.5| -45.4| -60  | -74.2| -87.8| -100.7| -113 |
| Beam angle (degree) |      |      |      |      |      |      |      |      |
| phase shift (degree)| 15.3 | 30.5 | 45.4 | 60   | 74.2 | 87.8 | -100.7| 113  |
4. Conclusion

The designed 5*5 array antenna can achieve maximum gain at main lobe 14 dBi each patch has its own feeder from phase shifter to control electronically the direction of main beam to track the non-geostationary satellites in orbit by change the phase shift of each feeder.

You can notice that the maximum gain decreases with the increase of offset angle so the limits of the angle is $40^\circ < \theta_0 < -40^\circ$ when the first side lobe power is half power of the main lobe.

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