LOW COST ANTENNA ELEMENTS FOR L-BAND MOBILE SATELLITE COMMUNICATIONS

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1. Introduction

The L-band mobile satellite communications program has extensively been investigated in different parts of the world including Australia [1], [2], Japan [3], USA [4], Canada [5] and some countries in Europe [6], [7]. As a result of this activity, various communications equipment has appeared in the commercial market [8]. The currently available antenna systems which are required in the land mobile satellite terminals are still quite expensive. For example, the cost of an electronically steerable vehicle mounted antenna can be in excess of three thousand US dollars. A briefcase antenna by Thrane & Thrane costs more than one thousand US dollars.

This paper describes the design and development of low cost, aperture coupled antenna elements for L-band mobile satellite communications. Using these antenna elements, a 2x2-element sequential array for possible use in a briefcase terminal is developed.

2. Antenna Requirements

A general difficulty associated with the design of antenna elements for mobile satellite communications is due to stringent requirements these antennas have to fulfil. These requirements include a set of electrical specifications together with extra desirable features such as low profile, low weight and low cost. For the mobile satellite system in Australia (Mobilesat), the electrical specifications stipulate VSWR less than 2, axial ratio less than 3dB (for right hand circular polarization) and gain greater than 6 dB over a 7% operational bandwidth including 1646.5-1660.5 MHz for transmission and 1545.0-1559.0 MHz for reception. Specifications for the other mobile satellite systems such as AMSC and Inmarsat are similar although the frequency band can be slightly wider and the required antenna gain can be higher than that for the Mobilesat system.

In [10] and [11], coaxially fed, cavity enclosed patch antennas have been developed which fulfil all the required electrical specifications for the Australian Mobilesat system. These antennas employ inexpensive materials including metal patches with air dielectric. However, the use of coaxial feeds make these antennas labour intensive to build. To reduce the manufacturing and assembling cost, aperture coupled microstrip patch antennas which employ low cost thin film material and foam can be explored. The design of antenna elements involving such low cost materials is described in the following sections. Two varieties of this type of antenna were considered: one - consisting of a circular patch with perturbation segements and a single feed, and the other - consisting of an unperturbed circular patch and a dual feed with a quadrature coupler as an external polariser. In the two cases, in order to increase the operational bandwidth, a special low dielectric foam between the patch and the feeding structure was used.

3. Perturbation Segmented Patch Antenna

Photograph 1 shows a single slot coupled perturbation segmented patch antenna. The patch is etched on a thin flim epoxy (thickness 0.076mm). The feed network is etched on a standard substrate RT/Duroid 5880 with $\epsilon_r=2.2$ and thickness 0.75 mm. A 6 mm thick foam sheet is placed between the patch and the feed network. The advantages of this new design is that it employs photographic production, uses no physical connections between the patch radiator and the feed network and includes only one connector for the input RF port. The patch radiator and the feed circuit can be assembled as tier layers with few screws.

By investigating the operation of this antenna, it was found that this structure could easily achieve the required impedance bandwidth. However, this was not the case for the ellipticity bandwidth. The attempts to obtain the required ellipticity bandwidth failed even for a 10mm thick foam. The situation was rectified using a stack patch configuration in which two patches with perturbation segments were used. This solution however was considered material and labour intensive and at this stage was rejected. The study of a single aperture fed patch with perturbation segments was therefore concluded unsuitable for application in Mobilesat antenna in a stand-alone format. As it is shown later in this paper, this configuration can however be useful for building a special type, fixed beam Mobilesat antenna array.

Because of the failure of a single aperture fed patch to deliver the required ellipticity bandwidth in a stand-alone configuration, an alternative, dual slot feed patch arrangement was studied.

4. Dual Slot Aperture Fed Patch Antenna

The required ellipticity bandwidth was easily achieved with a dual slot fed patch antenna which incorporated a branchline hybrid coupler as an external polariser. The antenna configuration is shown in photograph 2. The patch and hybrid coupler are etched on RT/Duroid 5880 substrate. For this configuration, an impedance bandwidth of 12% with centre frequency of 1.6 GHz was achieved. The CP antenna gain was 8.5 dBi and axial ratio was 1.6 dB over the Mobilesat frequency band. As such, this antenna was found suitable for Mobilesat application in a stand alone and array configurations.

5. 2x2 Element Sequential Array

As the single fed patch antenna could not meet the required ellipticity in a stand-alone arrangement, a 2x2 element sequential array was built to increase the ellipticity bandwidth. Photographs 3 and 4 show the array and the feed network, respectively. The 4-element array was produced on a thin flim epoxy with thickness of 0.076mm. The patches are aligned at 0°, 90°, 180° and 270° counter-clockwise. The feed circuit positioned behind the patch layer, was designed using 0° , 90° , 180° and 270° phase lags. These were achieved with three Wilkinson power dividers and delay lines. The array was assembled using foam, screws and spacers. The volume taken by this assembly without the package was 260 mm x 260 mm x14 mm.
The manufactured array was tested and showed gain of 12.5 dBi. The measured return loss was higher than 20 dB and axial ratio was 1.6 dB across the Mobilesat frequency band.
Due to its compact size, the array could easily be incorporated in the lid of a typical briefcase terminal. This solution was found more cost effective than a 2-element coaxially fed, cavity enclosed patch configuration which was described in [9].

6. Conclusions

Two configurations of aperture coupled microstrip patch antenna for use in L-band mobile satellite antenna system have been investigated. It has been found that a single fed patch antenna with perturbation segments can easily fulfil the required 7% impedance bandwidth but it fails to deliver the required ellipticity bandwidth. The required simultaneous impedance and ellipticity bandwidth can however be achieved with a dual fed aperture coupled patch which uses an external polariser in the form of a quadrature coupler. The ellipticity bandwidth for a single aperture fed patch can be enhanced by using it in a 2 x 2 element sequential array configuration. This array features the required impedance and ellipticity bandwith as well as a suitable gain to be used as a stand-alone Mobilesat antenna system. Due to its compact size it can for example be employed in a briefcase terminal. All the presented antenna elements and array are labour and cost effective and as such they should be found attractive from the production point of view.

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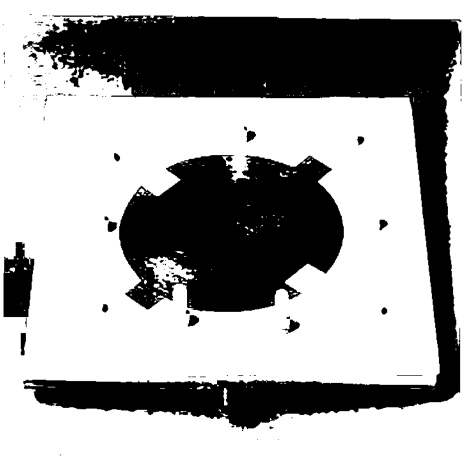

Fig. 1 Photograph of a single fed CP patch with perturbation segments.

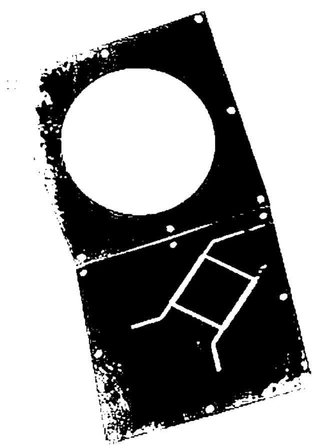

Fig2. Photograph of a dual fed CP patch with a branchline hybrid coupler.

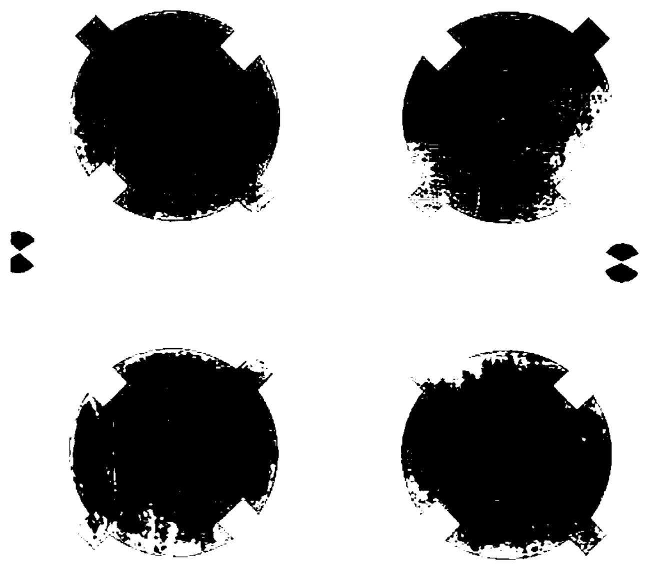

Fig.3 Photograph of 2x2 element sequentially rotated patch antenna array.

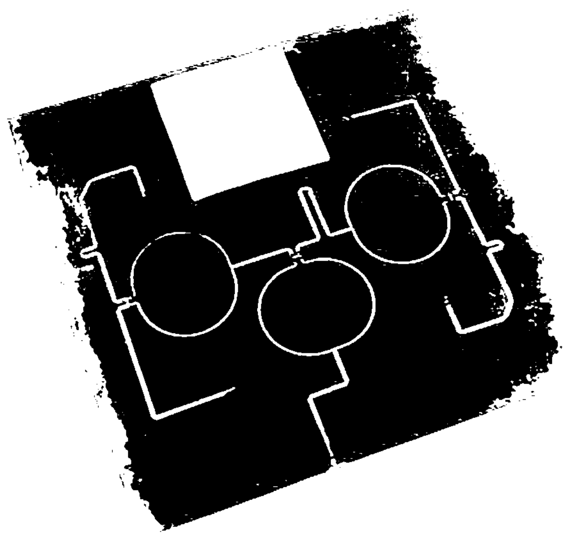

Fig.4 Photograph of the feed network (with a sample of foam) for the array shown in Figure 3.