Versatile, Stationary/Mobile Low-Cost Telecommunication System

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Abstract

We describe a low-cost, versatile microstrip antenna to be used for terrestrial to satellite fixed and mobile point to point links at Ku-band. The Ku band has recently attracted a great deal of attention in North America and Europe due to the available wide bandwidth and the propagation range, which has enabled it to be used for terrestrial and terrestrial-to-satellite links. This makes it particularly attractive for short and medium range communications. This link is versatile and can be re-configured on the fly to provide coverage and increasing omni-directional range.

The antenna discussed here can be used for satellite-to-earth communications, both from fixed and mobile terminals. One of the useful features are its ease of manufacture which therefore makes it low cost and easy to install in environments where this is a primary driver. Furthermore, the small-size attracts little attention and creates a stealthy package which is durable in extreme weather scenarios.

In conjunction with a low-cost front end radio, which is briefly described, this point-to-point telecommunication system can present a high-efficiency, ultra-low cost enabling platform for content delivery (internet, TV, etc.). Comparisons with other research of wide-area, low-cost network coverage will be provided.

I. INTRODUCTION

Low-cost point-to-point stationary and mobile antennas have become a very precious commodity in the telecommunications world, especially for regions with underdeveloped infrastructure, as they can provide one of the important building blocks of a versatile multi-media information network. The Ku-band of frequencies has been traditionally used for satellite up- and down-link using a narrow-band window (~500-800 MHz). In this work we illustrate the development of an antenna which can be used as the backbone of a simple communications system that can provide content delivery (Internet, TV, health informatics, news, etc.) to virtually any remote parts of the world.

II. ANTENNA ELEMENTS

At the core of the structure investigated in this paper, we have the basic building block antenna array for Ku-band satellite reception. As shown in Fig.1, the array is composed of 128 microstrip radiators grouped in four 4x8 subarrays **(1)**. Each subarray has a microstrip corporate feed network **(2)** while the four subarrays are connected to a waveguide network **(3)** operating as a corporate feed. The invented hybrid feed network reduces the array feed losses substantially since the waveguide corporate feed having a very low loss constitutes the backbone of the feed network. Using the invented hybrid feed network, one can increase the ratio of antenna gain to its noise temperature because a lower feed loss decreases antenna noise temperature.

The one-by-four waveguide feed network **(3)** is composed of various lengths of reduced height rectangular waveguides **(4)**, waveguide bends **(5)** and tees **(6)**, as well as waveguide-to-coaxial adapters **(7)**. The aforementioned bends and tees are of E-plane type, which simplifies the manufacture of the feed network. In other words, because of using E-plane waveguide components, the feed network can be manufactured from two metallic blocks each of which accommodates a half of the waveguide network. The components of this network are cut as grooves in two metallic blocks. Screws fasten the two metallic blocks. The input to this feed network **(8)**, and thus to the array, is a standard flange for WR75 rectangular waveguide whereas its outputs are four short coaxial waveguides which are part of the waveguide-to-coaxial adapter **(7)**.

Each of the four coaxial outputs of the waveguide feed network is coupled to one 4x8 subarray. The elements of this subarray **(9)** are circular microstrip antennas equipped with stubs and notches to achieve circular polarization for a given sense. By means of sequential rotation of the elements, the axial ratio of the subarray is maintained at values less than 1.5 dB in the neighborhood of the array boresight. A microstrip 4x8 corporate feed **(2)** is utilized to feed the elements of the subarray. The corporate feed and the elements are printed on a thin FR4 substrate **(10)** that forms the top layer of a two-layer substrate. The latter has a thick foam layer as its lower layer **(11)**. A thin low-loss double-sided tape binds the FR4 layer to the foam layer, and small nylon screws fasten the two-layer substrate onto the waveguide feed network.

While possessing high radiation efficiency because of low feed losses, the invented hybrid-feed array is very low cost. This makes the invented satellite antenna a suitable choice for low-cost household use.

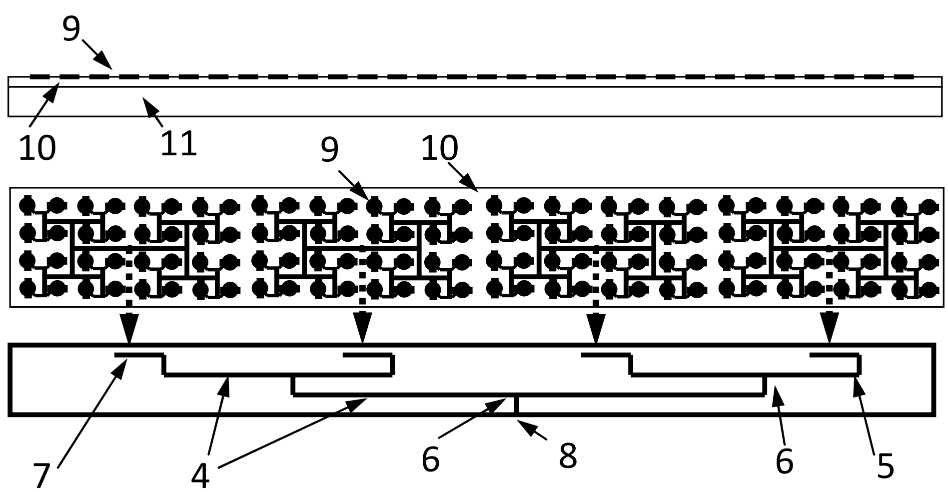

Fig. 1. Microstrip antenna building block.

III. ANTENNA MINIATURIZATION

In order to reduce the total height of a planar antenna array **(1)**, it is subdivided into subarrays **(2)** which then are arranged in parallel as demonstrated in Fig. 2. Using this arrangement, one is able to decrease the total height of the array, i.e. $N \times W$, by a factor inversely proportional to the number of subarrays N.

Fig. 3 depicts the geometrical parameters involved in this invention. In Fig. 3(a), the original antenna array is shown before decomposition. The width of the array is $N \times W$, where N is an integer. Fig. 3(b) shows the array after its decomposition into N subarrays each of width W. This has reduced the total height of the antenna array by $1/N$.

To avoid blockage of the array elements by the front subarrays, their spacing D must exceed a minimum. This minimum can be determined from the desired range of elevation angles. If the desired range of elevation angles has the mean value of *E*, the minimum value of *D*, denoted by $D_{\min}$ in Fig. 2(a), is related to *E* according to $\sin(E) = W / D_{\min}$.

If $D > D_{\min}$ is assumed, the radiation characteristics of the invented parallel configuration of Fig. 2(b) can approach that of the original array (Fig. 2(a)) for the elevation angles *E* within the range of

$$\tan^{-1}\left(\frac{H}{2D - \sqrt{W^2 - H^2}}\right) < E < \tan^{-1}\left(\frac{H}{2D - \sqrt{W^2 - H^2}}\right) + \pi / 2 \cdot$$

The above inequality is a result of application of the basic rules of geometrical optics to the center elements of the subarrays. As can be seen, the lower limit of the above range can be reduced by increasing the spacing of the subarrays.

It must be added that the highest possible similarity between the decomposed and the original array can only be achieved if the output signals of the subarrays undergo an electronic phase correction. In other words, the proposed configuration of the subarrays leads to a spatial phase shift of $2\pi D \cos(E) / \lambda$ between every two successive subarrays, where λ denotes the free-space wavelength. It is this spatial phase shift that must be compensated for using electronic phase shifters.

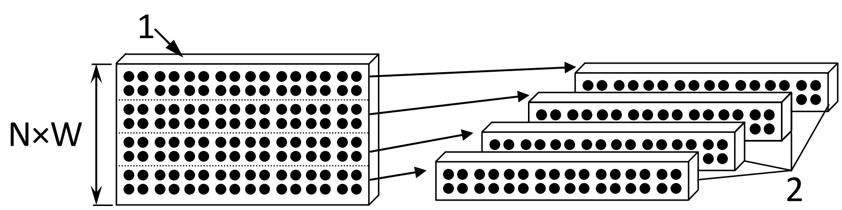

Fig. 2. Decomposition of a planar array **(1)** into parallel subarrays **(2)**.

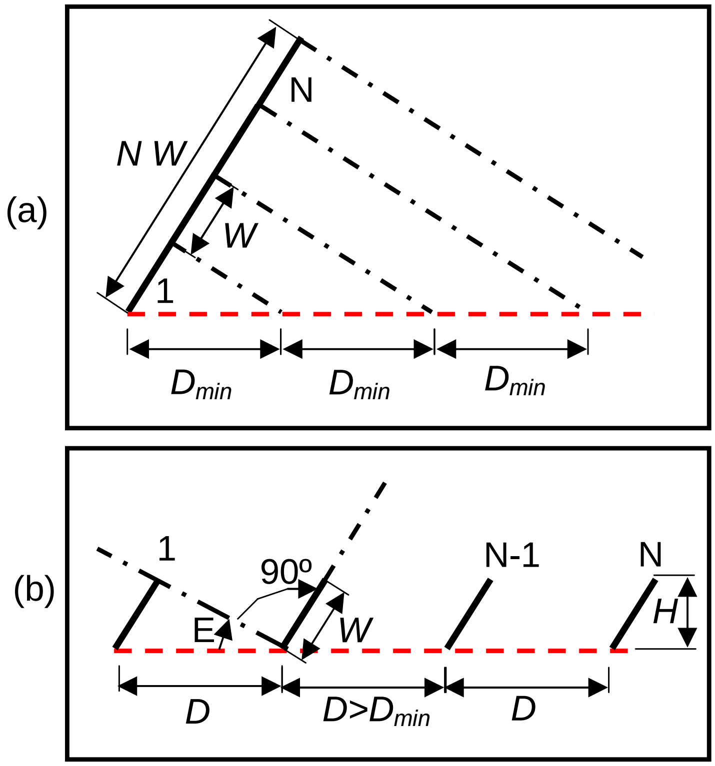

Fig. 3. (a) Side-view of the original planar antenna array, (b) decomposition of the array into *N* subarrays of width *W* and spacing *D*.

IV. COMPLETE SYSTEM

The low-profile complete antenna system that can be added on the roof of a vehicle or mounted stationary to receive existing satellite services in the Ku-band of frequencies while the vehicle is in motion or stationary. With respect to Fig. 4 and Fig 5., the system is composed of two high-efficiency high-gain arrays of 128 microstrip antennas **(1)** and **(2)** for reception of electromagnetic waves of right-hand and left-hand circular polarization, respectively. Each array is equipped with a low-noise block (LNB) **(3)** for down conversion of the received Ku-band signal to the intermediate frequency (IF). The output signals of the LNBs are combined using a channel selection switch. The output of the switch is directly connected to an off-the-shelf satellite receiver via a coaxial cable.

The arrays are assembled on a mechanical mount **(4)** which allows panel alignment in both the azimuth and elevation plane. The mount covers 720 degrees of azimuth angles and 50 degrees of elevation angles between 20º and 70º. The stepper motors **(5)** and **(6)** actuate the azimuth and elevation mechanism, respectively. A Global Positioning System (GPS) antenna **(7)** along with the rate gyros **(8)** provides the required feedback signals for the control unit **(9)**. Based on a control algorithm, the latter generates the necessary control currents for the azimuth and elevation stepper motors **(5)** and **(6)** to align the main beam of the antenna arrays **(1)** and **(2)** with the satellite boresight while the car undergoes various maneuvers.

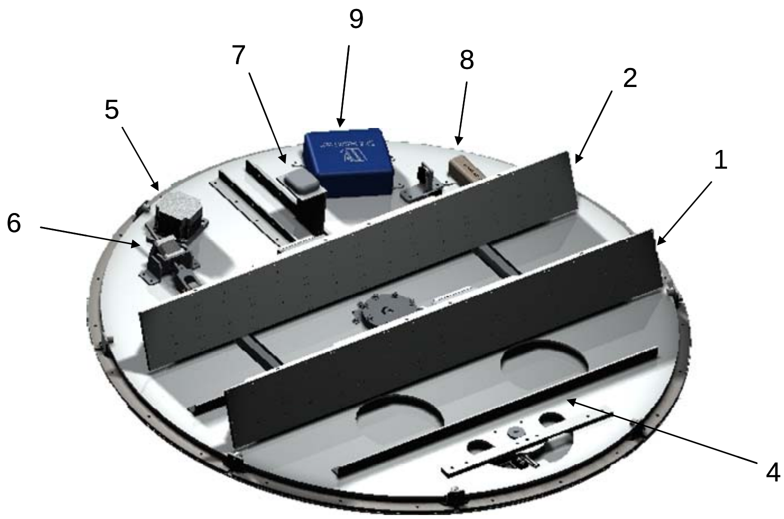

Fig 4. Front isometric view.

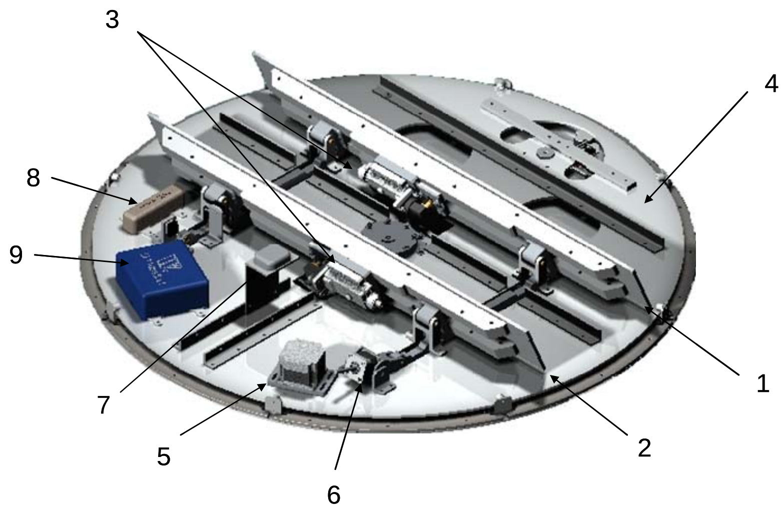

Fig 5. Rear isometric view

IV. CONCLUSION

We have presented a general, versatile antenna telecommunications system for earth-to-satellite communications. This can be used in a variety of scenarios from stationary to mobile links and can be made available in a variety of configurations to suit harsh temperature environments.

The development of the low-cost front end which accompanies the antenna described here to complete the package will be investigated in a future paper.

V. ACKNOWLEDGEMENT

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REFERENCES

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