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LMDS BASE STATION ANTENNA DESIGN

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Abstract

The design of a feed network for a 24 x 2 stratified linearly polarized patch array is presented in this article. This design is a candidate for an LMDS Base Station antenna and complies with ETSI Standard requirements such as polarization, bandwidth, gain, -3 dB beamwidths and Side lobe levels. The feed network has been designed to produce appropriate unequal power excitation for each patch and a match condition at the feed point. Unequal distribution of the power improves the side lobe level. From simulation, the array antenna yields -23 dB return loss in the LMDS band, narrow -3 dB beamwidths of 2.9° and 46° in the elevation plane and azimuth plane respectively, high gain of 23 dB and 7.5 % bandwidth satisfying with ETSI Standard.

Introduction

Millimeter wave communication systems in the 24 GHz to 30 GHz band are being developed in the United States for use in a Local Multipoint Distribution Service (LMDS). These systems with large usable bandwidth are envisioned to support full duplex, high data rate applications such as high-speed Internet, interactive video, broadcast voice and digital television channels [1]. To bring LMDS to the masses, certain technical hurdles will have to be overcome, including the development of low cost, small size, high-gain and narrow beam antenna [2]. Because of their low profile, low weight, low cost and easy manufacturing, microstrip antenna are the best candidates for the design of LMDS Base Station antennas [3]. This article describes the design of a antenna array that must satisfy with ETSI Standard for LMDS application [4].

LMDS Base Station Antenna Design

Array synthesis

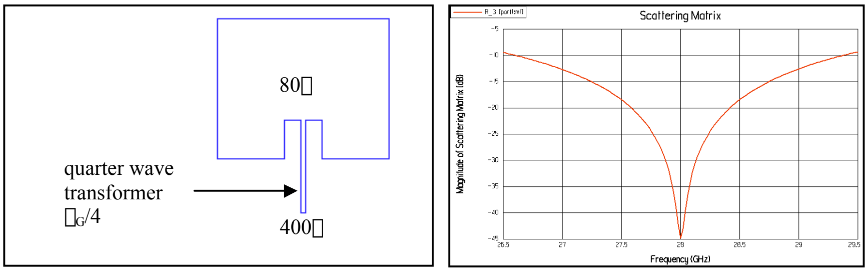
Antenna array consisting of an appropriate number of patches, patch weight and distance between two neighboring elements must comply with the ETSI Standard requirements. The side lobe level and -3 dB beamwidth are dictated by the weight and the number of patches respectively. The distance between two neighbor patches allows both parameters to vary. All parameters have been determined using 1D Array Analysis Software. 24 patches in the elevation plane and 2 in the azimuth plane satisfied beamwidth as prescribed by ETSI Standard. Ideal weights for 12 elements (use of symmetrical network) with two neighboring elements distanced by $0.75\lambda_0$ (360° phase shift) are described in *Table 1* giving side lobe level of -30 dB.

Element	1	2	3	4	5	6	7	8	9	10	11	12
Weights Magnitude	0.2	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.8	0.9	1	1

Table 1 : *Ideal weight for 12 elements*

Design of a single element

Figure 1(a) shows a single-feed arrangement for a rectangular patch antenna to produce linear polarization and an input impedance $Z_{inp} = 400\ \Omega$.



(a) ***(b)***

***Figure 1 : (a)** Single Patch Element, **(b)** Return loss referenced to 400 Ω*

Figure 1(b) shows the computer-predicted return loss as function of frequency, using Ensemble □ v.8 [5].

Study of element coupling

The study of the coupling effect between elements in large antenna array is a very important step in the spatial positioning of the array elements. Since the distance between two successive patches in the azimuth plane is critical (half λ_0), the coupling effect will affect either the frequency parameters and the radiation pattern if the two patches are collinear in the E-plane. To overcome this effect, the two patches are separated spatially by an adequate distance $\lambda_g/2$ corresponding to 180°. To avoid physical overlapping and coupling between patches and feed network, a 180° phase difference between the electromagnetic field vectors of two successive patches in the E-plane has been introduced.

Feed network

An hybrid (parallel-series) feed network is well suited for a planar array antenna, each-fed element antenna phase is the same (see *figure 2*).

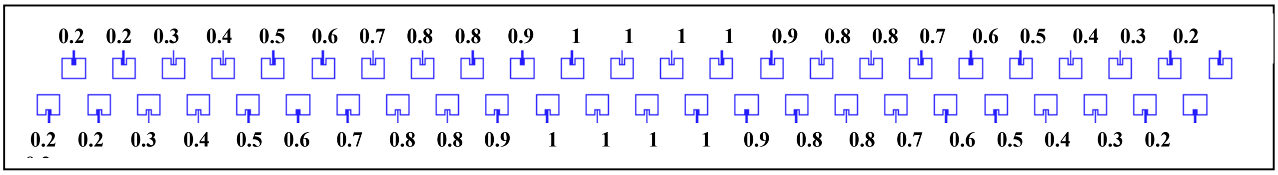


***Figure 2 :** Ideal feed network*

The power splitters used in the feed network consist of 44 quarter-wave transformers; consequently, it is not possible to obtain closed form solutions for the design. The design is therefore based on the required power split for each patch, the maximum realizable impedance values for the microstrip lines to reduce spurious radiation and coupling by the feed network, and to obtain a match at the feed point [6]. The equivalent input impedance at each junction is dictated by the weight of the patches as illustrated in *Figure 3*.

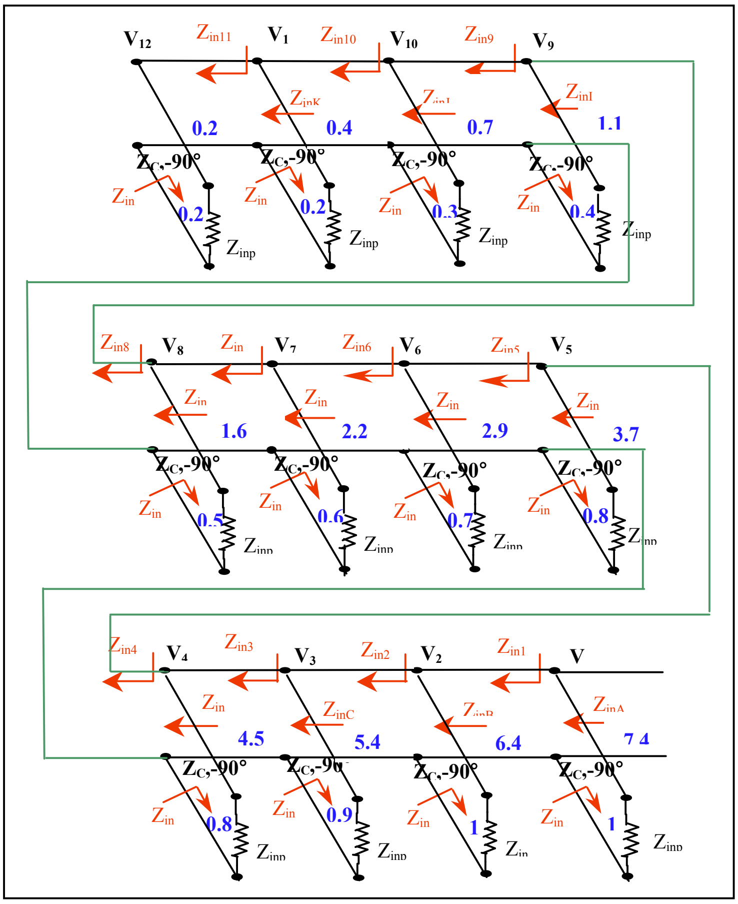


***Figure 3 :** 12 element network*

For instance, At junction V_{10} :

$$Z_{in10}=\frac{0.3\times Z_{in}}{0.4}=300\Omega \quad (1)$$

the equivalent input Z_{inJ} impedance is

$$Z_{inJ}=\frac{Z_{in}\times Z_{in10}}{Z_{in}+Z_{in10}}=171.4\Omega \quad (2)$$

The same procedure has been applied to calculate the equivalent input impedance at the junctions.
Two neighbor patches are separated by 360° phase shift (0.75λ_0) of the order of λ_g. Four quarter wave transformers have been introduced between two neighbor patches, and their characteristic impedances determined as illustrated in *Figure 4* for patch 12 and 11. Assumptions have been made for three of these characteristic impedances considering that the highest characteristic impedance that can be practically realized using Teflon (ε_r = 2.2, h = 0.762 mm, tanδ = 0.002) is $Z_0 = 210\ \Omega$. Z_{44}, Z_{43}, Z_{42} have been assumed in order to calculate the characteristic impedance Z_{41}.

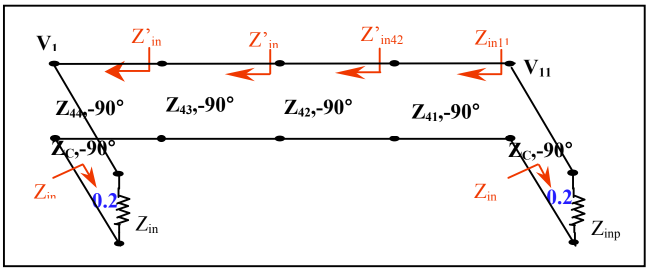


Figure 4 : *Patch 12 and 11*

The same technique has been used to calculate the characteristic impedance of all 44 quarter wave transformers. There is not a unique solution, but it has been considered that further the patch is from the array center, lesser the weight of the patch and highest the characteristic impedance. The array is illustrated in *Figure 5*.

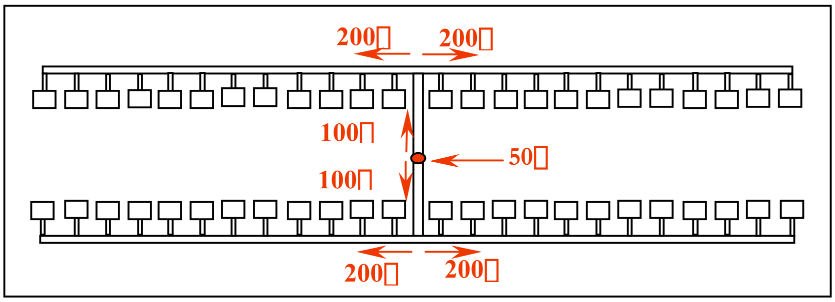


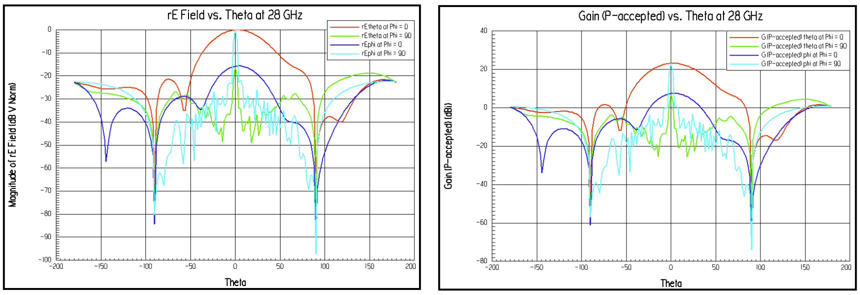
Figure 5 : *24×2 antenna array*

To match Z_{inA} to 200 Ω (see *Figure 3* and *Figure 5*), two-quarter wave transformers have been introduced. The 12 element network has been simulated using Serenade® v8.7 [7] in order to determine the real weights of the patch as well as the real input impedance of the network. Black boxes have been introduced representing the simulated single patch (using Ensemble®). At 28 GHz, an input impedance of 214 Ω has been determined for 12 elements, agreeing with predicted value of 200 Ω. The real weights of the patches are illustrated in *Table 2*.

Element	1	2	3	4	5	6	7	8	9	10	11	12
Weights Magnitude	0.36	0.36	0.46	0.54	0.61	0.68	0.71	0.79	0.79	0.86	0.93	1

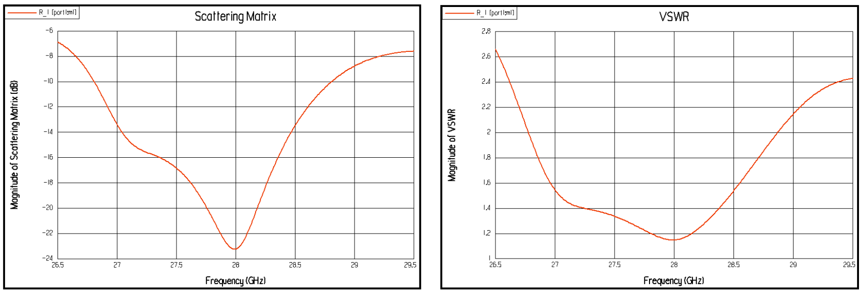
Table 2 : *Real weights of the patches*

Since coupling has appeared between parallel feed network and patches at the center of the array, a stratified configuration has been used. The infinite ground plane is sandwiched between two substrates (Teflon). The series feed network containing the patch has been designed on Substrate 1 and the parallel feed network on Substrate 2. The two substrates are connected to the centers of the two series feed network by two via. The 24 × 2 patch array (illustrated in *Figure 9*) has been designed and simulated using Ensemble ® v8. A first simulation has proved that the array was unmatched with a return loss of -12 dB at 27.3 GHz. To improve matching network, a stub designed at 28 GHz has been introduced in the design. The 24 × 2 antenna array is illustrated in *Figure 8*. The computer predicted results polar pattern and gain as a function of angle are illustrated in *Figure 7(a)* and *Figure 7(b)* respectively, *Figure 8(a)* represents return loss and *Figure 8(b)* represents VSWR.



(a) ***(b)***

Figure 6 : *Radiation Pattern and gain at 27.7GHz*



(a) ***(b)***

Figure 7 : *Return loss and VSWR referenced to 50Ω*

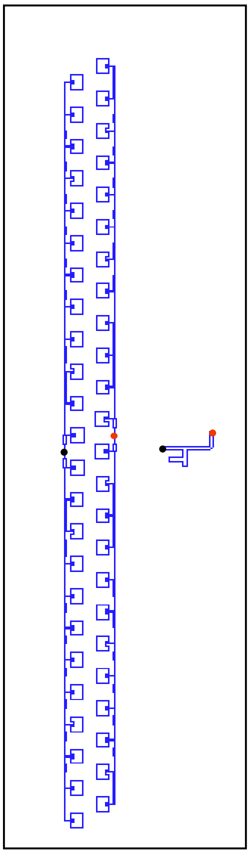


Figure 8 : *24×2 antenna array*

Conclusion

A microstrip single patch antenna has been developed and yields linear polarization and high input impedance. A parallel-series feed network was utilized to improve radiation pattern, gain and bandwidth. A series-feed network was designed from Dolph-Chebyshev method for a -35 dB side lobe level while the simulated side lobe level shows -23 dB due to the feed network. The array antenna producing matching at the feed point provides 23 dB gain and 2.9° and 46° -3 dB beamwidth in the elevation plane and azimuth plane respectively, satisfying with ETSI Standard. The bandwidth has been slightly reduced for the array antenna due to the use of series feed network, achieving 2.6 GHz bandwidth (10 %) for single patch and 2.1 GHz bandwidth (7.5 %) for the array. Since the use of via has been shown to be detrimental to manufacturing yield at LMDS band, this work has been restricted to the design and simulation of an array prototype for LMDS system.

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