A 20 GHz ACTIVE RECEIVE SLOT ARRAY†

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1. Introduction

A 20 GHz active receive slot array has been developed for operation in the downlink frequency band of NASA's Advanced Communication Technology Satellite (ACTS) for the ACTS Mobile Terminal (AMT) project. The AMT is to demonstrate voice and data communication between a mobile terminal in Los Angeles, CA, and a fixed terminal in Cleveland, OH, via the ACTS satellite [1]. Satellite tracking for the land-mobile vehicular antenna system involves "mechanical dithering" of the antenna, where the antenna system radiates a fixed beam 46° above the horizon, receiving vertical polarization and transmitting horizontal polarization at 20 and 30 GHz, respectively. The active receive array was designed as a light weight, low profile rugged active antenna, with low-cost, high-volume production potential with easy integration of active integrated circuit components.

The active receive array, to be mounted on an 8-inch diameter turntable, operates over the frequency range 19.914-20.064 GHz with a minimum system G/T greater than −8 dB/°K. The main beam points in a fixed direction 46° above the horizon, with an elevation beamwidth at least 12°, to compensate for vehicle pitch and yaw.

The active antenna consists of an array of fourteen linear series-fdty[m microstrip slot arrays, fourteen packaged Monolithic Microwave Integrated Circuit (MMIC) low noise amplifier (LNA) submodules connected at each subarray output, a 14-way Wilkinson-type power divider, and a final additional LNA submodule used as a driver amplifier. The active receive array was designed to achieve the receive sensitivity requirement by placing the LNAs as close as possible to the antenna subarrays, minimizing the losses that occur in front, of the amplifiers. The additional driver amplifier further minimizes system G/T sensitivity to losses that follow the antenna.

2. Slot Array

The slot array consists of fourteen linear subarrays spaced $0.648\lambda_0$ apart. Each linear series-fed-type subarray consists of eight slot elements transversely, electromagnetically coupled to a shielded microstrip line as shown in Figure 1 [2]. Each subarray was designed using transmission line theory with each slot modeled as a series impedance. Characterization of the slot elements as a function of offset was performed both theoretically and experimentally. Amplitude distribution along the array is primarily a function of the element offsets while the main beam direction is primarily a function of the interelement spacing. While vertical shorting pins placed between the slotted plane and the shielding ground plane were necessary to suppress undesired wave propagation for a single linear subarray [2], for the 14-column array, little difference was seen in measured patterns and gain with and without the shorting pins. The directivity of the array is approximately 22.3 dB and the insertion loss was measured to be approximately 0.5- 1.0 dB.

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3. MMIC Module

‘1’0 provide a low-cost proof- of-concept active module for commercial applications, the active array development effort incorporated commercial MMICs housed in off-the-shelf microwave device packages [3]. To exceed the minimum G/’l’ specification of −8 d] 1/°K, the LNA submodules required $\leq$ 4.0 dB noise figures and $\geq$ 17.5 dB gain. Each LNA subn iodule consists of two TRW AT ,011102C M MIC 1,NAs housed in a standard package from St ratEdge Corporation and mounted on a subcarrier. LNAs with a low noise figure (< 3.3 dB) were selected to be in the first stage of the package and those with higher gain (> 9 d] 3) were selected to be in the second stage. The submodules exhibited an average noise figure of 3.9 dB and an average gain of 18 dB.

The MMIC receive module, consisting of 14 LNA submodules, a novel 14-way Wilkinson power divider [4], and a driver LNA submodule at the output, was tested and found to have approximately 19.8 dB gain through each of the 14 paths, with a maximum gain variation of ±1.0 dB and a maximum phase variation of :1:110.

4. Experimental Results

A prototype active antenna, shown in Figure 2, is modular in design, where each of the components, the array, the LNA submodules, and the power divider, are mounted onto a single base plate by screws for testability and reworkability. A nice feature of the! antenna design is that all circuitry and devices, i.e., the power dividing network, the microstrip lines of each subarray, and the LNAs, are enclosed within the antenna fixture. 1 Radiation from the antenna occurs only through the slot radiating elements, thus minimizing EMC issues. Measured radiation patterns of the active receive array are shown in Figure 3. Measured gain of the active array, relative to a standard gain horn (approximately 24 dB at 19.914 GHz), is shown in Figure 4. And finally, experimental results indicate that G/T at the beam peak is approximately --5+ 1 dB/°K.

5. References

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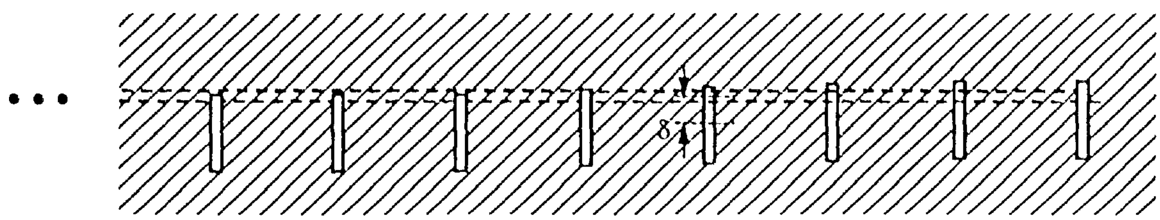
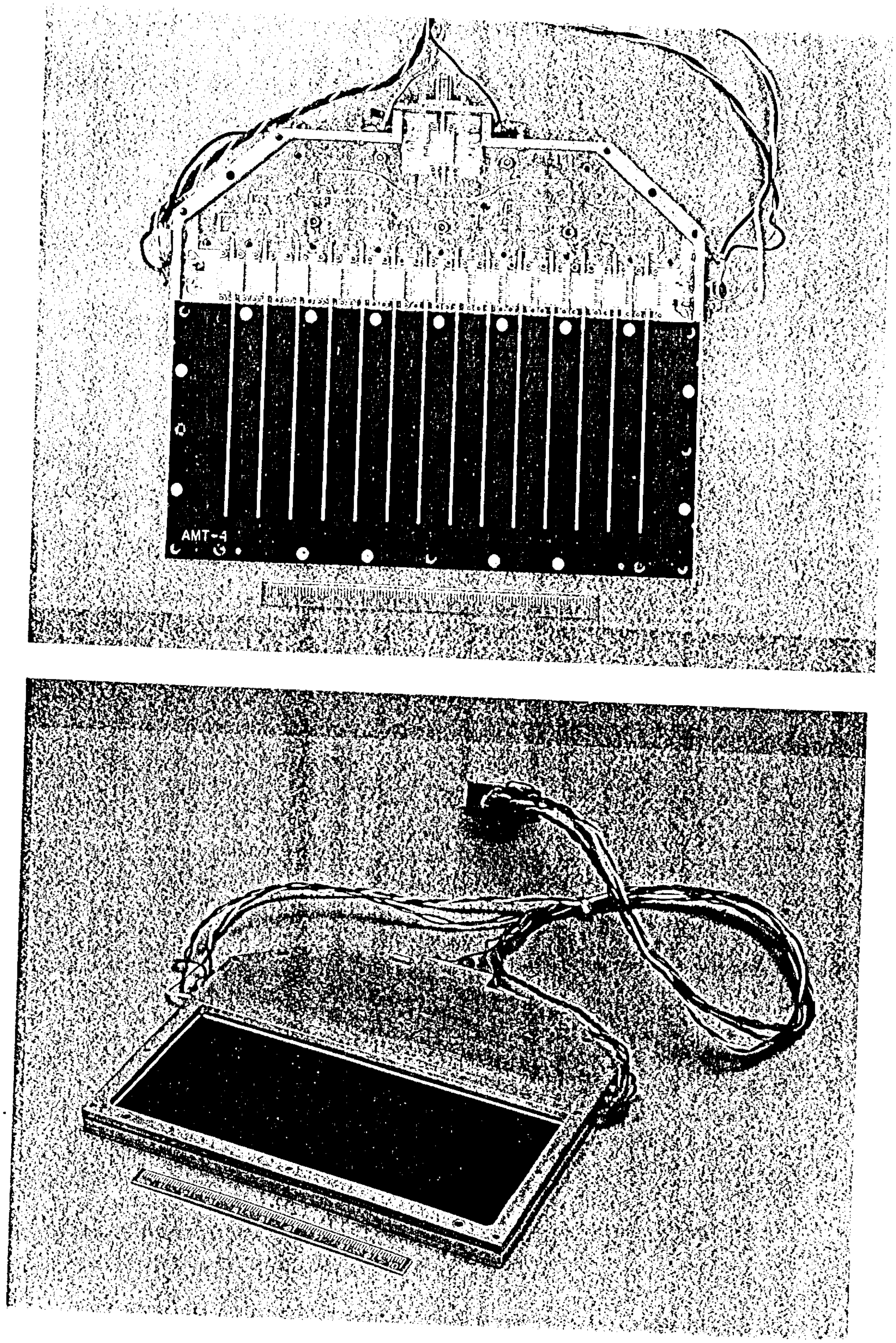


Figure 1. Linear slot subarray.



(a)

(b)

Figure 2. Active receive array. (a) View without back plate. (b) Complete assembly.

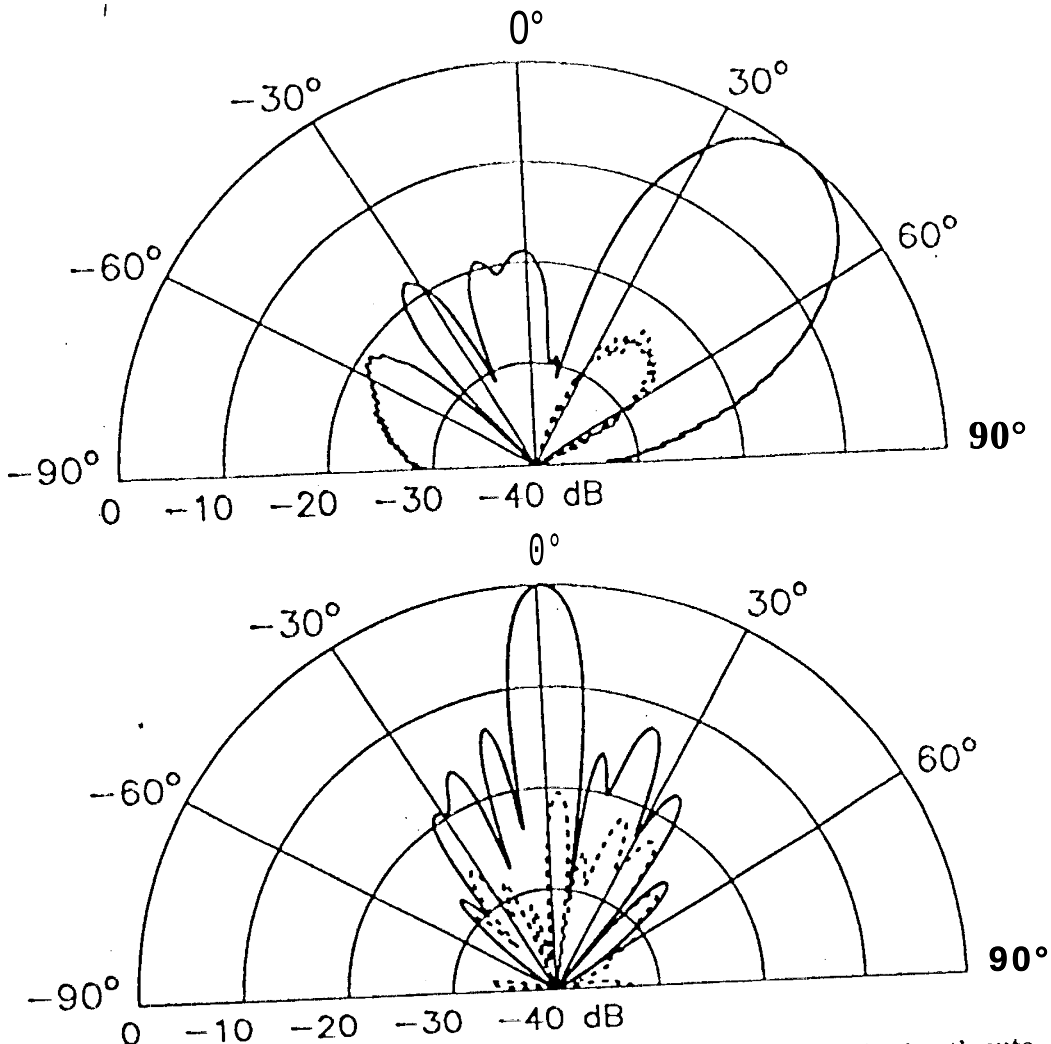


Figure 3. Measured radiation patterns at 19.91 GHz. Elevation and azimuth cuts.

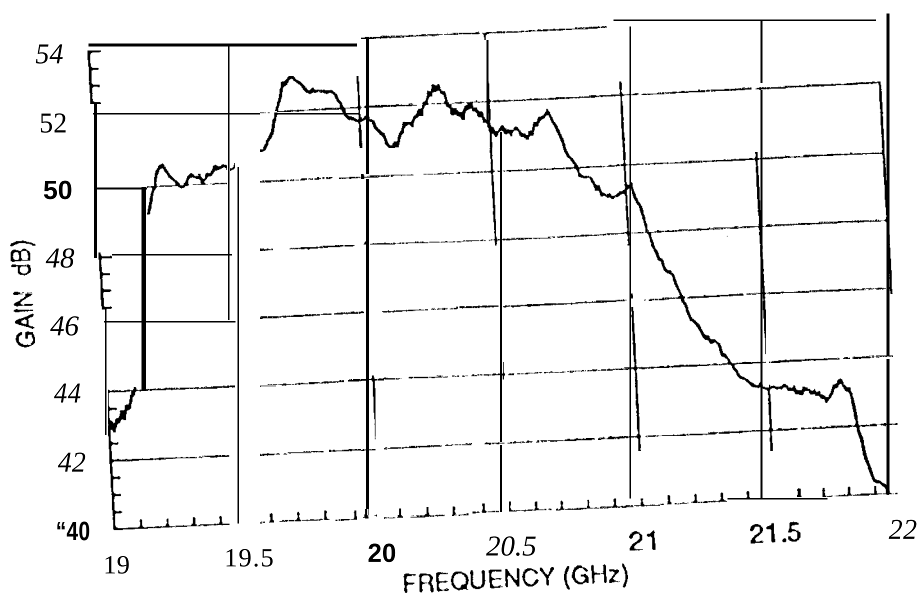


Figure 4. Measured gain of active receive array.