SIMPLIFIED ANTENNA DESIGN FOR TELEMETRY STATIONS

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ABSTRACT

PSL is developing a telemetry antenna intended to avoid the mechanical complexity of traditional parabolic passive monopulse trackers. For a considerable range of reception scenarios, a stationary non-tracking antenna will fill the reception requirement while greatly simplyfing the antenna hardware as compared to mechanical passive trackers. A single, phi-symmetric, shaped-beam antenna provides proper coverage of the test range for multiple airborne targets. This system is not time shared and requires no acquisition time. Approximate azimuth to the target is displayed on a CRT. This paper examines the applicable test scenario and the resulting hardware. Keywords: antennas, multiple targets, telemetry.

INTRODUCTION

The antenna selected for telemetry ground stations usually is one of two extremes: a simple, single element which provides the essential coverage required, or a high gain reflector system using a passive monopulse tracker or external radar direction. The simplest antennas do not optimally cover the test volume, and the complexity and expense of a tracking system is frequently over-kill. Antennas designed over a continuum of complexities between these limits can be employed which can perform satisfactorily and are cost effective. This paper presents analysis of a specific telemetry application and the antenna design configured to its demands.

The motivation for this design effort was a customer's requirement for a low cost downlink telemetry system at a specific test range. The mechanical tracking systems employed for TM reception had become a major expense and maintenance problem. Additionally, some features of the tracker's operation were inconvenient to the project. For most missions, the high gain of the dish is not required, and more modest gain could be employed in favor of other advantages.

PSL conducted an analysis of this overall operation and designed an antenna whose performance over much of the test envelope is equivalent to the original equipment, but which is simpler and less expensive. The technical approach and tradeoff considerations used in this analysis are appropriate to a large variety of situations. First, the overall site operational scenario will be examined. Then the antenna performance and coverage that meets the site requirements will be calculated. An antenna that satisfies these needs will then be described together with the limitations and tradeoffs.

SITE LAYOUT AND REQUIREMENTS

The application employs downlink only TM from helicopter-borne systems. Several targets may be simultaneously active on different channels. The test vehicles originate from pads very close to the ground station. Telemetry is required between one mile and 40 miles from the ground station, and from near ground level to 20,000 feet. The test site and operational envelope are depicted in Figure 1. The angle θ shown is the range-dependent elevation angle to the target. The vehicle employs a 1485 MHz skin mounted antenna with approximately hemispherical coverage, and a minimum ERP of 10 watts at the usable geometry limits.

The customer currently employs tracking dishes at the site. While RF performance is satisfactory, the installation complexity has become prohibitive with several targets present. Since the targets maneuver independently, a dedicated tracker is required for each. They are co-located and a look through problem occurs during tracking. The trackers provide very accurate angle-to-target information, but this information is not used in the data analysis. Only approximate target azimuth angle is required for operator assurance of visual linkup to the proper vehicle. Consideration of the RF signal strength and vehicle operational envelope can result in an antenna of substantially simplified design.

RF LINK CALCULATIONS

To obtain a value for the needed antenna gain, calculation of the expected receiver power, including the effects of multipath interference, is first conducted.

To achieve a 10^{-6} bit error rate, a 15 dB carrier-to-noise ratio is required. Using a 6 MHz channel width results in noise power of −106.2 dBm, therefore −91 dBm is required at the receiver to meet the C/N. The worst case ERP of +40 dBm provides power to a unity gain antenna of $P = 40 - [20\ 1og(4\pi R)/\lambda]$. Noting that the signal at 40 miles is −92.1 dBm, only 1.1 dB of antenna gain is required in the absence of multipath. Unless the antenna beamwidth is sufficiently narrow to discriminate the target from its reflection image, multipath cannot be ignored (1). Adequate antenna gain margin must be provided to protect against anticipated multipath fading.

This margin is selected to allow proper signal to be available at the receiver in the worst expected nulls. Statistically, arbitrarily deep nulls may sometimes occur. However, an expected-worst case “frequent” fade level may be anticipated by consideration of the reflection which might arise. Near grazing angles, perfect surfaces reflect efficiently regardless of their composition. However, rough surfaces provide more than one isolated specular point. A significant area contributes energy which is diffuse and therefore sums imperfectly (2). The resultant nulls are not as deep as would be calculated for a single contributor. Carver (3), Drexler (4), and Straiton (5) reported on reflections from carefully prepared test ranges. The theoretically obtainable 6 dB gain (6) due to image theory was never observed. Measured values were about 5 dB and more typically 4 dB. The high sensitivity of null depth with respect to voltage reflection coefficient is shown in Figure 2. This means that the highest indicated electric field reflectivities were in the 0.7 to 0.8 range (3,5). These values decrease rapidly with roughness. For even moderately rough terrain, 0.6 appears to be the highest expected reflectivity at grazing incidence. The resultant null depth is calculated from $P_{null} = 20 \log(1-\Gamma)$. For a Γ of 0.6, a fading of −8 dB with respect to the unperturbed signal is produced.

For this geometry, excess antenna gain of 8 dBi will protect against statistically frequent multipath fades. To assure 15 dB C/N in multipath nulls at a maximum range will therefore require 9.1 dBi.

PATTERN SYNTHESIS

Using the RF link calculation and the test geometry, the needed beamshape is defined. Power received from the target varies with the slant range R as $1/R^2$. Therefore, for constant power, the familiar result is $G = KCSC^2$. In this case, constant power is unnecessary, and the simpler objective $G \geq KCSC^2$ will be sought. This will be obtained by a weighted array in the vertical direction (7). The previously obtained 9.1 dBi is required from edge to edge of the test volume and is assumed to be the −3 dB point of a 12.1 dBi mainbeam. The maximum possible theoretical gain for a phi-symmetric antenna subtending 20K ft at 40 miles (5.4 deg) is 12.7 dBi. Two other factors affect the final gain objective.

The element azimuth pattern has an approximate 90 deg 6 dB beamwidth requiring the use of 4 vertical arrays to complete the phi-symmetric azimuth pattern. Pattern degradation in azimuth is approximately 2 dB (Figure 3). Since a net 12.1 dBi is required everywhere, this raises the required peak gain to 13.1 dBi. Finally, the vertical angular displacement of image from the target does provide some multipath rejection. At the 40 mile distance, the reflection is rejected by 8 dB for a 20K ft vehicle height, reducing to zero rejection at ground level. Therefore, if a small degradation of the 15 dB C/N is permitted at maximum range near ground level, the available 12.7 dBi will suffice. For most of the envelope, the performance will be adequate. In the unusual case of a low level mission at extreme range, one of the existing tracking systems may provide better performance for a single target.

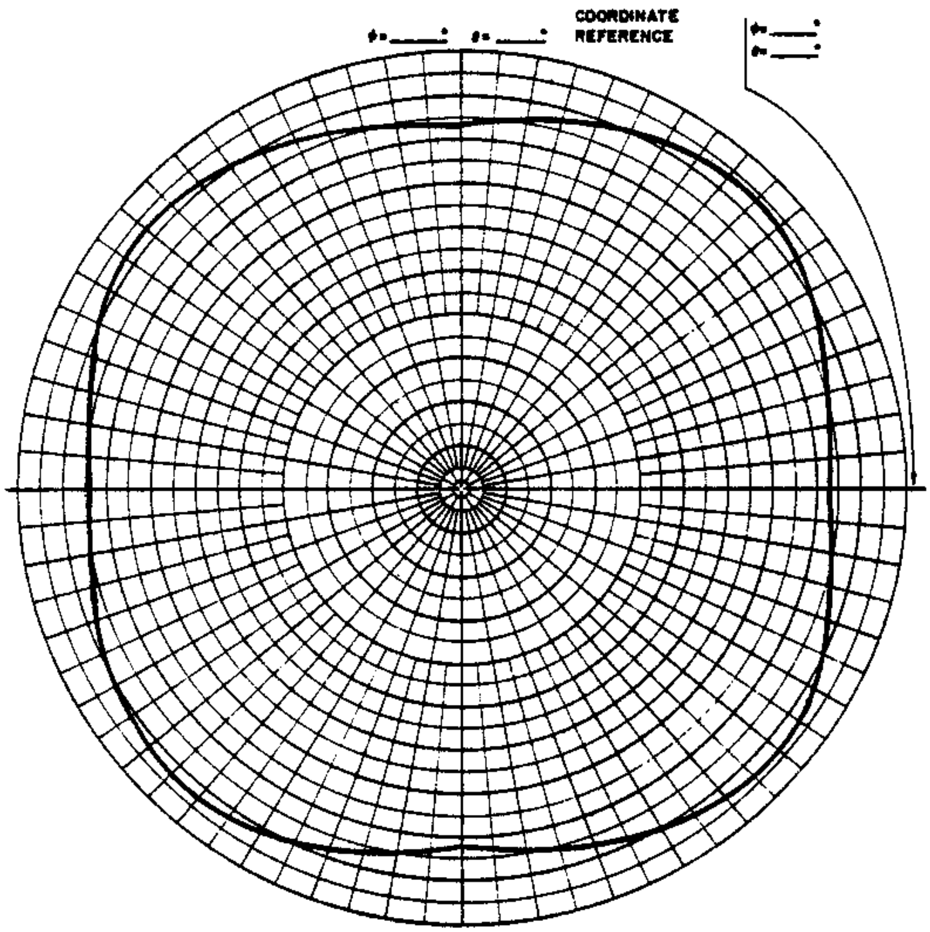

Figure 3 - Azimuthal Pattern Ripple

MULTIPLE TARGET OPERATION

Up to seven vehicles may operate simultaneously with unique frequency assignments. Each target is assigned a dedicated receiver which is fed from the power divider output. An RF pre-amp at the antenna base is included to assure sufficient signal.

Site operation requires only approximate target azimuth information. This is obtained by sampling the individual array outputs and summing detected video on a vector scope. System functional operation is shown in Figure 4. Individual channels are frequency selected and coded for strobe identification. Since intermittent dropouts in the azimuth display are not significant, the sampling is low level to reduce the effect on the receiver signal.

CONCLUSION

We have presented a solution for a specific TM situation which alleviates many of the shortcomings of the existing tracking receiver system. Lower maintenance, no acquisition/re-acquisition time, inherent multiple channel capability, and simplified operational requirements are the main advantages. A slight performance penalty is paid for very low-angle, long-range targets. Many ranges whose operational envelope allow the use of less gain than is available in a steerable dish might benefit from this approach.

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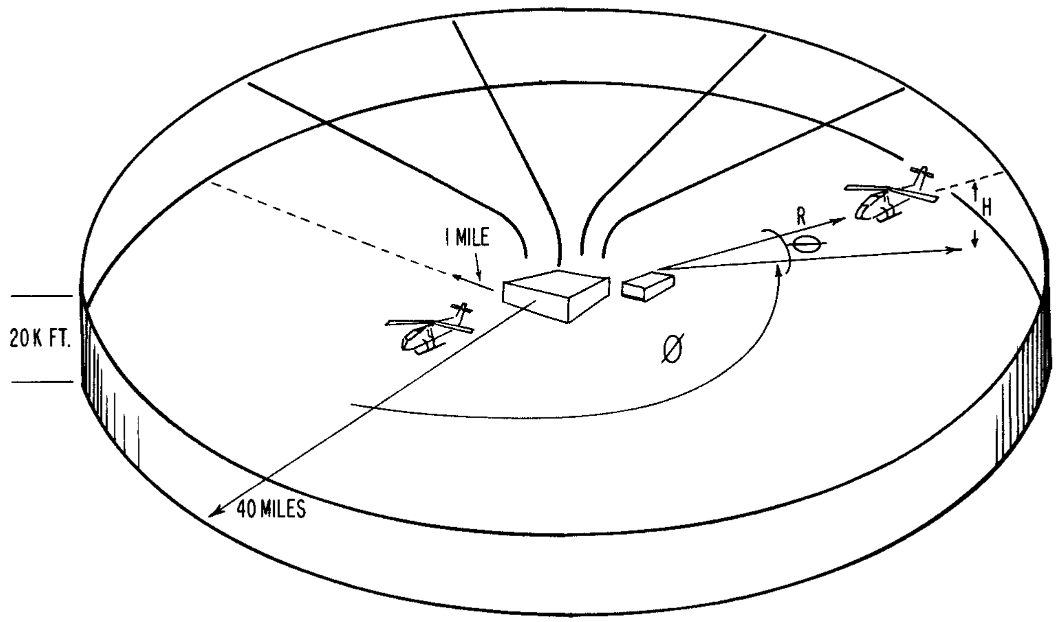

Figure 1 - Test Site

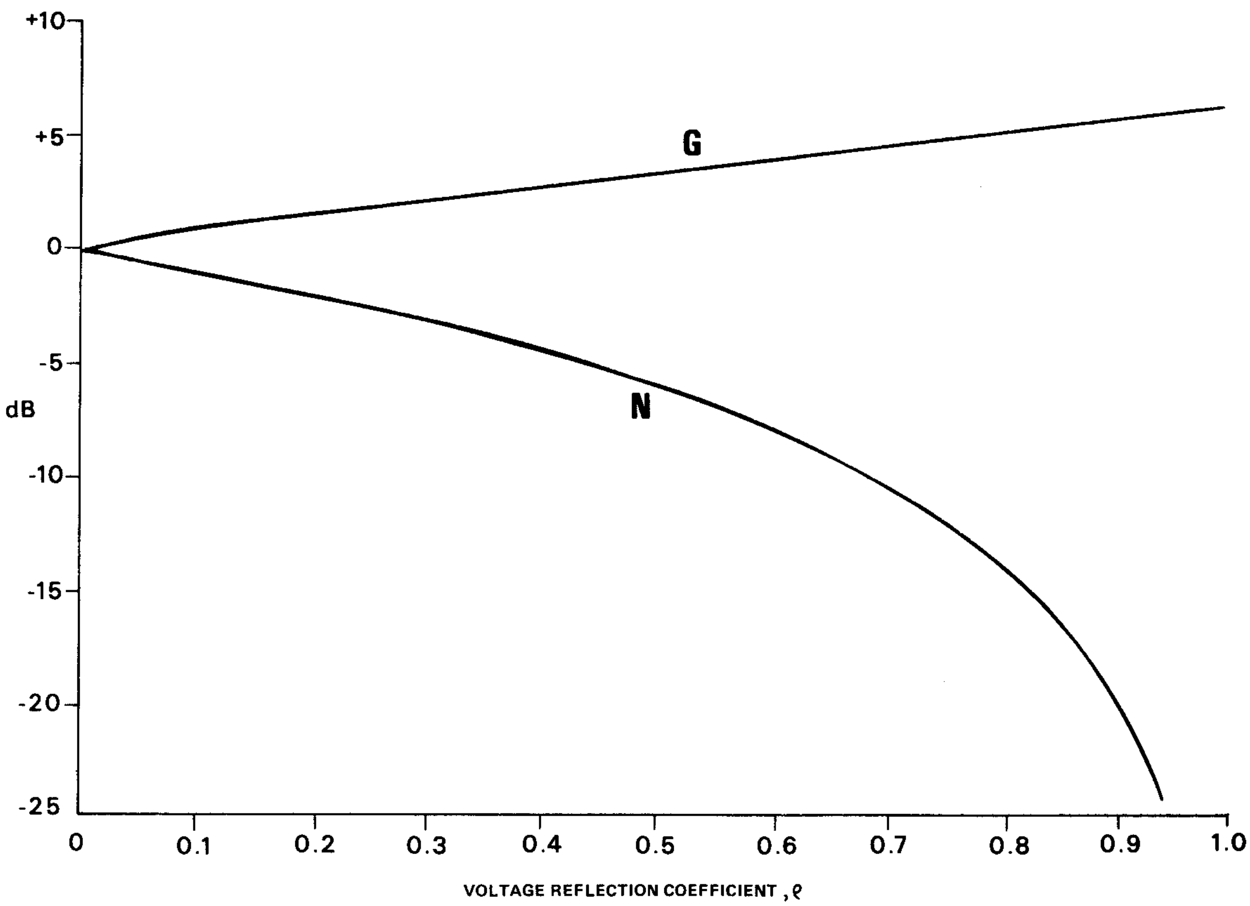

Figure 2 - Gain & Null Depth for Reflective Surfaces

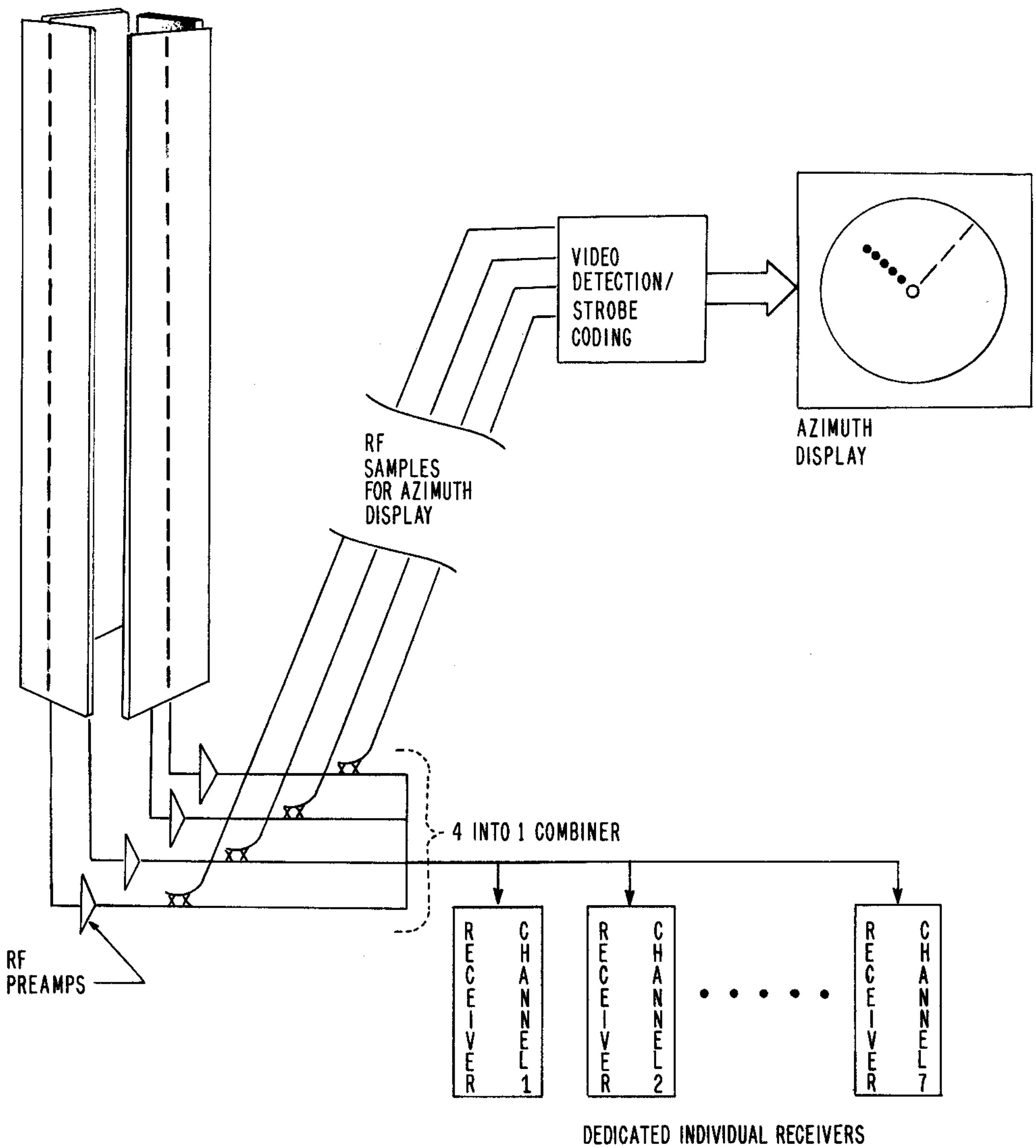

Figure 4 - System Functional Operation