AUTONOMOUS GROUND STATION FOR SATELLITE COMMUNICATIONS

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ABSTRACT

Employment of the retro-directive technique described in Reference 1 describes a totally Autonomous Ground Station providing hemispheric coverage and continuous tracking. This System establishes communications between the satellite and ground station without human intervention or moving parts. When a satellite is in view, the ground station beacon antenna, using CDMA, enables the desired satellite transmitter and directs its beam to the ground station. The ground station, using the satellite's transmitted signal, directs it's receive and transmit arrays to point the ground station beams to the satellite, establishing two-way communications. The process is automatic and provides continuous horizon to horizon tracking.

KEY WORDS

Phased arrays, signal processing, unwanted signal nulling, hemispheric coverage, thinned arrays, and automatic signal acquisition.

INTRODUCTION

Ground stations for satellite communications that are manned three shifts per day/seven days a week have become increasingly expensive to operate and maintain. In addition, there are situations where a ground station is only needed in a particular area for a short period of time. A portable system, which could be employed in another location at a later time, would be the ideal solution, i.e., a readily transportable system. Employment of the retro-directive technique described in refs.1 and 2 presents the possibility of a totally Autonomous Ground Station that provides both hemispheric coverage and continuous tracking. This System also eliminates the "keyhole" found in most dish antenna systems. The System envisioned would establish communications between satellite and ground station without requiring human intervention or moving parts, and, using an error signal developed in Reference 3, offers the possibility of nulling unwanted signals. When a satellite is to be in view, the ground station beacon antenna, using for example Code

Division Multiple Access (CDMA), turns on the desired satellite transmitter and directs its retro-directive or tracking beam to the ground station. The ground station in turn, using the satellite's transmitted signal, phases-up its receive and transmit arrays so as to point the ground station beams to the satellite, thereby establishing two-way communications. The process is automatic and provides continuous horizon to horizon tracking.

Use of the CDMA to separate the user satellites would allow simultaneous communications with multiple satellites, while providing 30 dB separation when using the gold codes.

This System requires no apriori knowledge of source location. It is totally automated, requires very little maintenance and no manual intervention; and over its lifetime should prove cost effective.

Figure 1 shows a typical system configuration, while Figure 2 is a suggested antenna arrangement for X-Band. Each of the four arrays in Figure 2 provides coverage in excess of ±50° in both elevation and azimuthal planes, thereby providing total hemispheric coverage.

The sequence of operations would call for the ground station to send an omni-directional beacon signal that turns on the desired satellite. This signal should be of narrow bandwidth to reduce the power requirements. The satellite, in turn, transmits a signal that allows the ground station to phase-up both the transmit and receive arrays, so as to point their beams to the satellite, thereby establishing two-way communications.

As described in Reference 1, the ground station receive array employs a few sensor elements arrayed both horizontally and vertically, that measure phase differences generated by the satellite signal incident on the sensor elements. This is known as a thinned array. A total of nine sensor elements in each planar array of Figure 2 are sufficient to generate all phases required to scan each planar array in both planes, i.e., in azimuth and elevation.

The only software required for the system to operate is that which seeds the ground station beacon, so as to turn-on the desired satellite. Thereafter, signal acquisition, beam formation and tracking is automatic. This requires no phase shifters, moving parts or a priori knowledge of signal source location.

Complete hemispheric coverage is thereby achieved by employing four planar arrays, as shown in Figure 2, each mounted on a face of a four sided pyramid inclined at 45°. Radiation coverage by each array is greater than ±45°, thereby providing continuous coverage over the entire hemisphere, both in elevation and in azimuth. Receive and transmit phases for each of the array elements are determined by measuring quantities containing the phase differences generated by a signal incident on a few interferometer pairs, ie., on thinned arrays. The need for phase shifters or switches is eliminated. By generating a radiation pattern that is orthogonal to the conventional sum pattern, nulling of unwanted signals is greatly simplified.

Nulling of unwanted signals can be accomplished by generating two independent radiation patterns using the same receiver array. First is the conventional sum pattern with its on-axis maximum response and associated side lobes. The second pattern is orthogonal to the first and has a null on-axis rather than a maximum. A summation of appropriate harmonics produces a radiation pattern that approximates a signum function, i.e., a response that is uniformly positive for all positive spatial angles, uniformly negative for all negative spatial angles and zero at array zenith. Figure 3. This zero response is independently scannable relative to the sum channel. By placing the null in the direction of an unwanted signal and multiplying the two antenna patterns, the unwanted signal is eliminated while not affecting the desired signal.

Additional receivers can be added to the same array for multiple user support in a CDMA System with full array gain available to each user simultaneously. Power dividers are placed after amplification of the signal and are routed to each user receiver. The CDMA code is reduced to provide the carrier and information to be processed. Each user would use a separate subset of phase combiners (mixers) which would form independent beams for each user.

The Local Oscillators could be shared for all users as the desired directional information is contained in the carrier after removal of the CDMA code. This enables the same array to support multiple users simultaneously.

Each user would require the use of a separate array for transmit from the ground station for directivity of the beam. This does not normally pose a problem as the transmit beam usually is formed using fewer, higher power transmit elements.

REFERENCES

1. Kaiser, Julius A., “Retrodirective Antenna System”, ITC Conference Program, Las Vegas, NV, July, 1995.

2. Kaiser, Julius A., “Single Beam Synthesis from Thinned Arrays”, Journal of the Acoustical Society of America. Vol. 76, No. 2, August 1984, pp. 465-474.

3. U.S. Patent 5,339,284, “Signal Processor for Elimination of Sidelobe Responses and Generation of Error Signals”, assigned to FH&A.

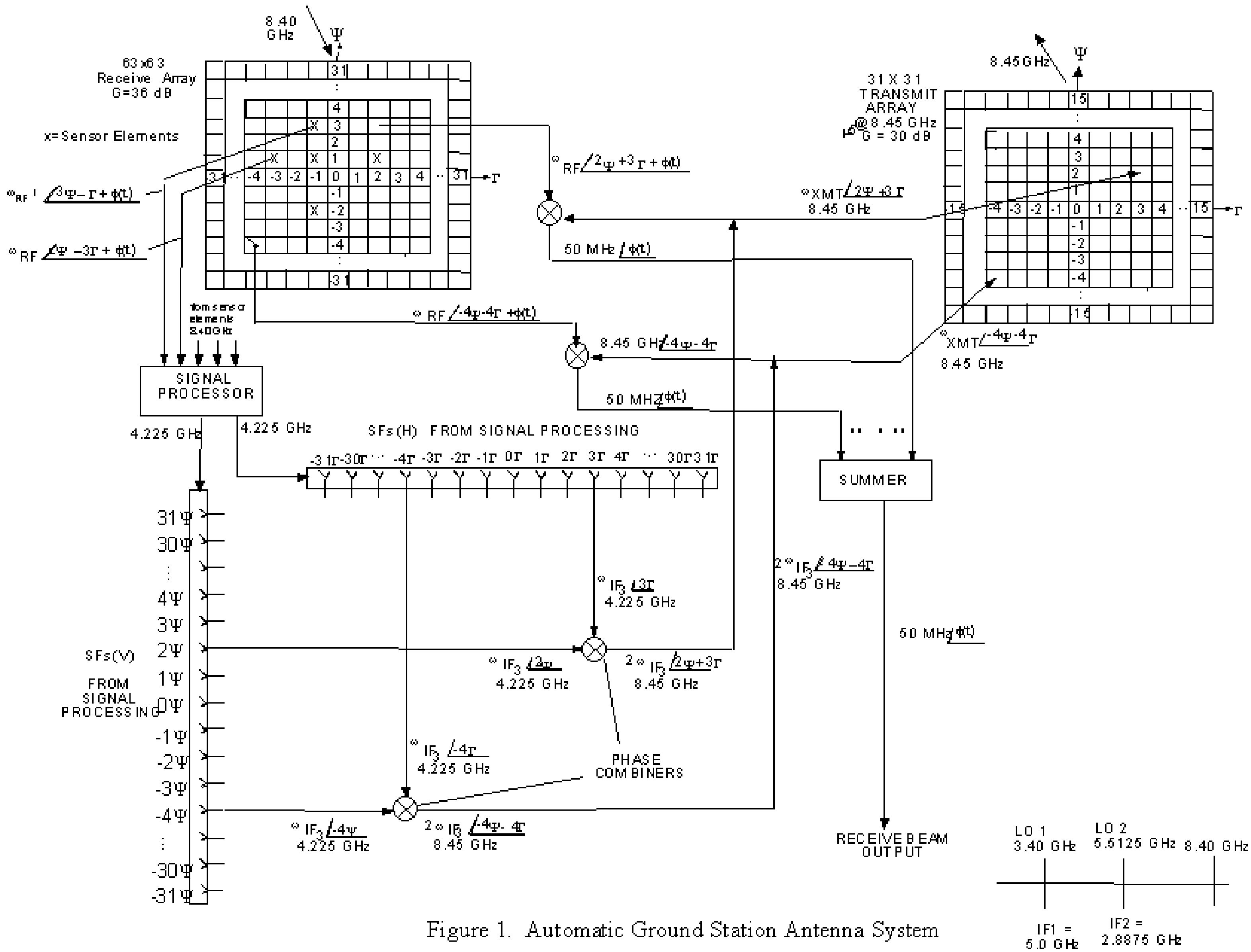

Figure 1. Automatic Ground Station Antenna System

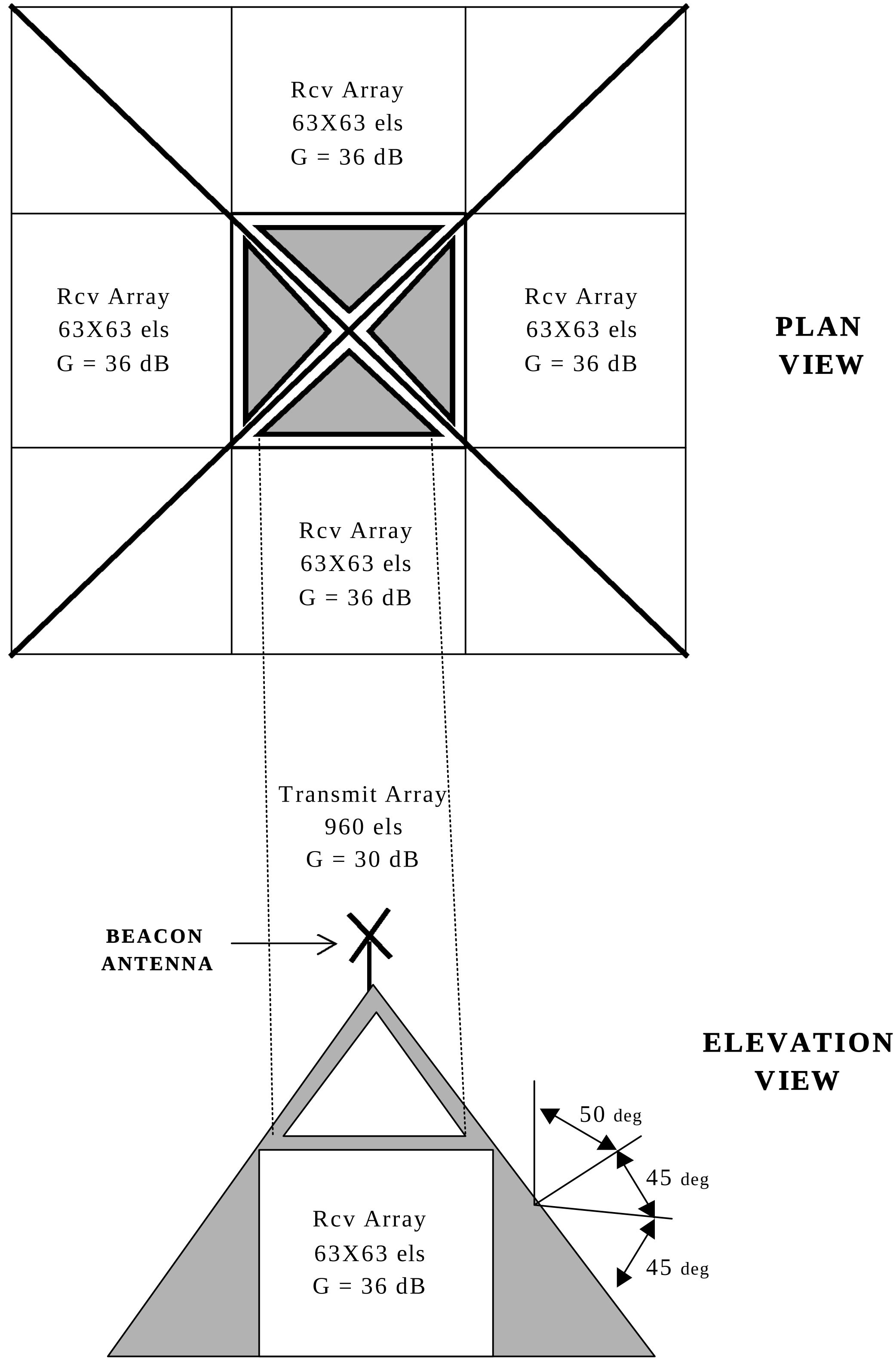

Figure 2. Ground Station Antenna Arrays

$n := 8$

$$\theta := \frac{-\pi}{2}, \frac{-\pi}{6} .. \frac{\pi}{2} \qquad I := 1 .. \frac{n}{2}$$

$$\sum_{I} \left[\left(\left(\frac{1}{2 \cdot I - 1} \right) \right) \cdot \sin\left[(2 \cdot I - 1) \cdot \frac{\pi}{2} \cdot \sin(\theta) \right] \right]$$

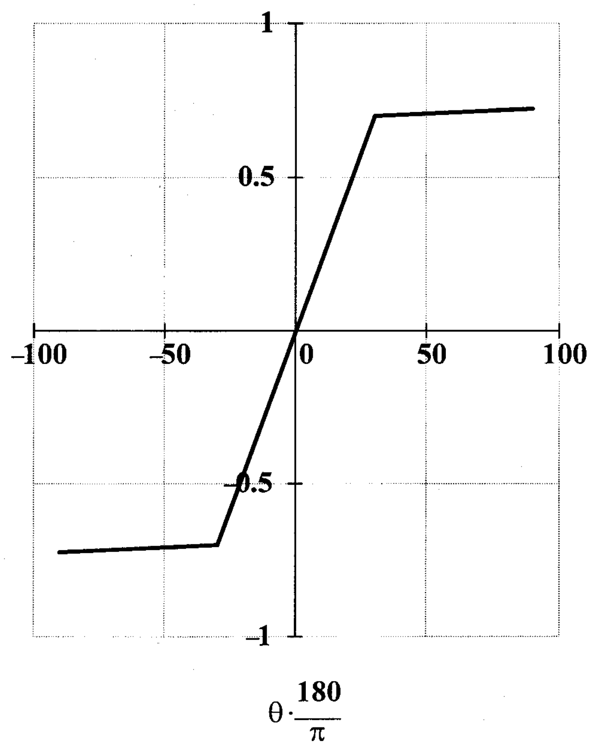

Figure 3. Error Signal