ADAPTIVE GROUND IMPLEMENTED PHASED ARRAY

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One of the more significant problems facing the designers of the tracking data relay satellite (TDRS) is that of establishing a VHF system design. The design must be tolerant of the high level radio frequency interference (RFI) environment which may be encountered by the TDRS and its low data rate users. An adaptive ground implemented phased array (AGIPA) can provide significant improvements in signal-to-RFI ratio.

Studies conducted for and by Goddard Space Flight Center have shown that the RFI levels received by a synchronous altitude satellite would range considerably above the channel thermal noise for a fixed field of view antenna coverage as depicted in Figure 1. The TDRS

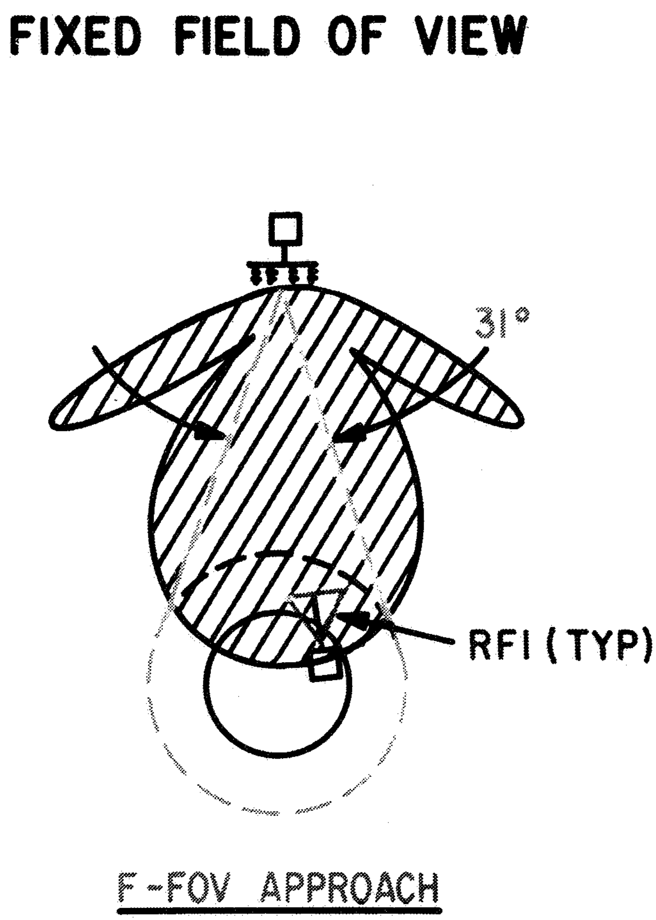


Figure 1. Antenna coverage, fixed field of view.

requirements for the low data rate channel are to provide a means for up to twenty satellites to simultaneously use the TDRS. The fixed field of view antenna would not afford reliable service for these users even in the absence of RFI.

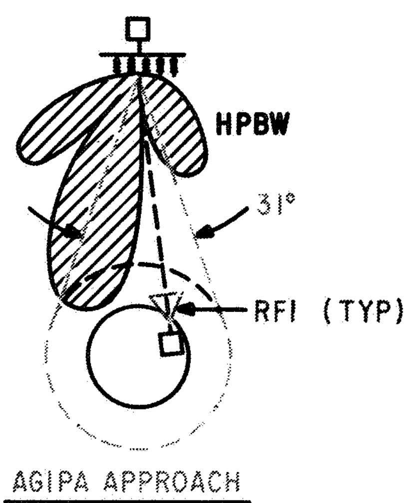
A study conducted by Magnavox for GSFC concluded that the most efficient method of operation for the LDR link is to make use of wideband spread spectrum PSK modulation techniques which would provide:

- Multiple Access
- Multipath Rejection
- Processing Gain Against RFI

Further analysis of the link requirements indicated that even more processing gain than that afforded by utilization of the entire 2 MHz VHF bandwidth is required.

The only other potential area of improvement is to increase the directivity of the antenna beam, which would result in rejection of RFI outside the antenna field of view and increase the signal gain as in Figure 2. Consequently, an approach was devised using a phased array

AGIPA



- ADAPTIVE GROUND IMPLEMENTED PHASED ARRAY
- ADAPTIVE SPATIAL FILTERING OF RFI
- ADAPTIVE POLARIZATION FILTERING OF RFI

} FOR MAXIMUM SIR

- HPW-8° SR AGIPA (5λ) (VARIABLE 4°-13°)

Figure 2. Adaptive ground implemented phased array.

which could form an independent narrow beam for each user satellite without requiring complex system implementation in the TDRS.

The technique which was evolved utilized the TDRS as a platform for five VHF antenna array elements. It relayed the signals from each antenna element to the ground station (GS) where all of the adaptive beam forming, beam steering, and signal processing could be performed, thus alleviating the normal complexities and physical constraints involved in spaceborne signal processing of multiple signals.

An adaptive ground implemented phased array (AGIPA) retains the advantages of a high gain array with only a small amount of additional on-board equipment, while providing as many independent narrow tracking beams as there are user satellites. The overall TDRS system using AGIPA is shown in Figure 3.

Signals originating from low altitude user satellites are received at the TDRS by the five element VHF ring array. Both horizontal and vertical polarizations from each of the five antenna array elements are multiplexed and transmitted down to the ground station (GS). Therefore, ten individual channels, one for the vertical and horizontal output of each antenna element are relayed to the GS via the Ku-band TDRS-GS transmission link.

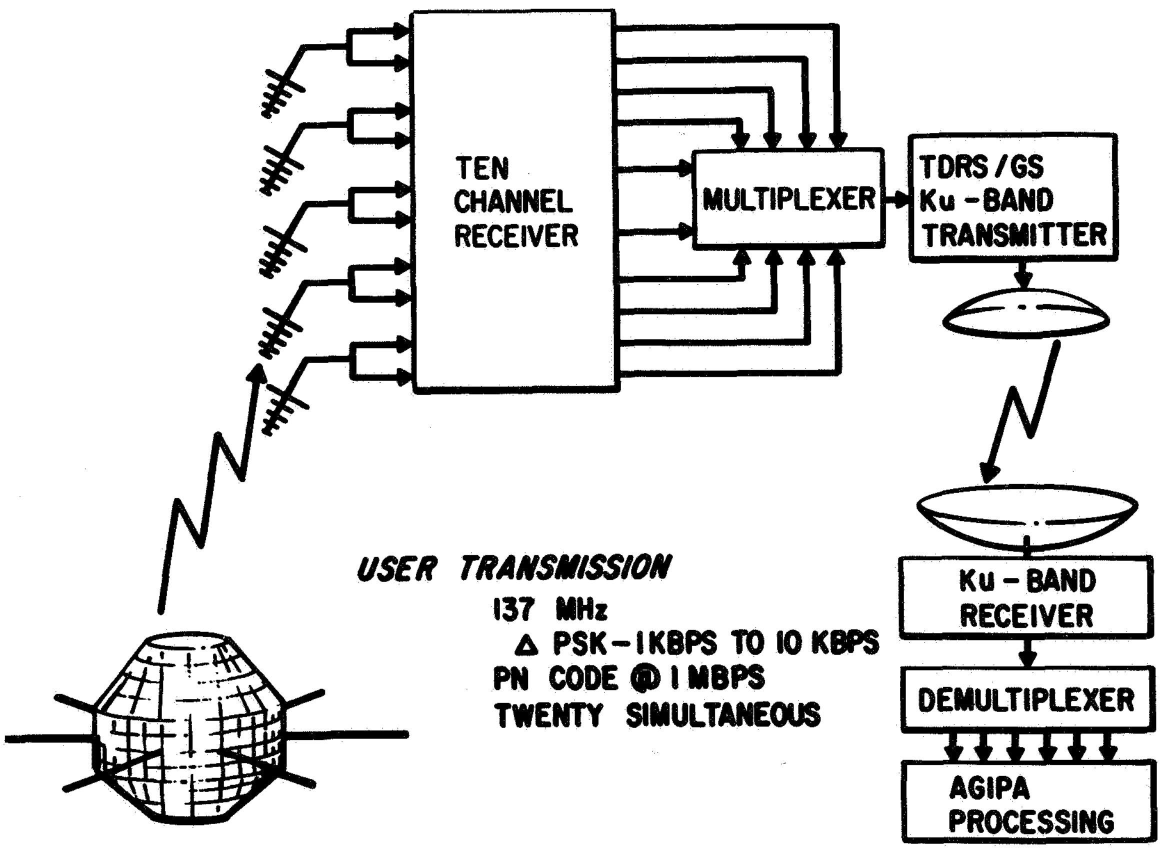


Figure 3. AGIPA implementation for TDRS.

On the ground the unique pseudo-random code transmitted by each LDR satellite is utilized to separate the different received signals into forty channels, one for each user. Thus, the contribution from each array element is made available for each user, enabling the computer controlled adaptive signal processing receiver to individually synthesize a tracking beam which maximizes the signal-to-interference ratio.

The method devised to evaluate the performance of the AGIPA system was to simulate the user to TDRS to ground station portion of the return link. The VHF array was scaled to S-band so that the demonstration tests could be performed inside of an anechoic chamber with a range of between 9 and 15 m (30 and 50 ft). To simulate the actual environment which the TDRS will encounter, there are up to ten S-band RFI sources at 2298 MHz ±1 MHz located on a panel at the transmitting end of the chamber; along with the desired signal, which is mounted on a pulley system to simulate the dynamic relationship between user and TDRS. Figure 4 illustrates this arrangement.

The multiplexer-demultiplexer and Ku-band TDRS-GS link, although important parts of the overall system, are not required in evaluating AGIPA performance and will therefore not be implemented during this development program. The five S-band array elements are

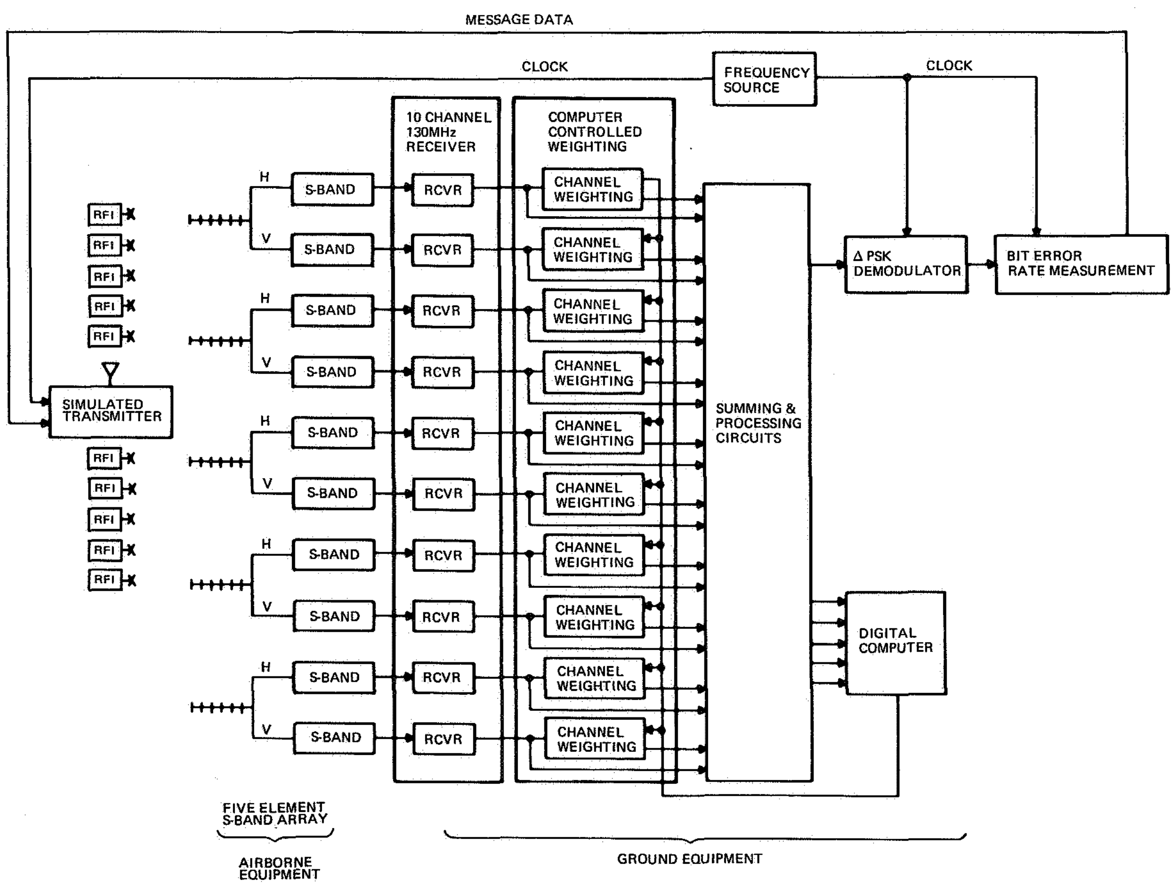


Figure 4. Simulated AGIPA system.

thus connected directly to an S-band front end which translates the received spectrum to the 137 MHz VHF operating frequency. Thus, all the RF processing circuits are implemented at the TDRS design frequency so that the circuit parameters are directly transferable to actual TDRS requirements.

The GS processing consists of weighting the amplitude and phase of each of the ten array channels, so that the beam formed adaptively places the RFI signals in nulls, and the desired signal near or on the peak of the beam depending on the condition which optimizes S/RFI. The 10 input channels are summed and the desired sum signal and the interference sum signals are separated. In parallel with the summing process, the desired signal and interference signals from the individual input channels are also identified and separated. The resultant desired and interference signals from the sum and individual channels are correlated, and the correlator outputs are used to compute the proper amplitude weighting and phase adjustments for the beam steering and shaping network. The proper values and direction of correction to be applied to the amplitude weighting and phase adjustment network are made in a computer. This is programmed to make iterative changes until the resultant sum signal-to-interference ratio has been maximized. The adaptive signal processor utilizes amplitude and phase, as well as polarization information from the desired and interference signals, to effectively point the major lobe of the array pattern to the desired signal; it is simultaneously putting a null on the interference signals. To accomplish this, however, the desired signal need not always be on the peak or near the peak of the major lobe in order to maximize the signal-to-interference ratio, but may frequently be well off the peak.

Testing performed using the simulation equipment has demonstrated that a good correlation exists between predicted and actual results. Figure 5 illustrates the optimization achieved for a typical scenario of the Atlantic region. The peak of the antenna beam can be seen pointing near the spacecraft position, with the majority of interfering sources located at or near nulls in the antenna beam. Improvements in low data rate performance using this technique have ranged up to approximately 15 dB. As a result of this demonstrated performance, the AGIPA concept has been incorporated as part of the design baseline for TDRS Phase B study program which is presently in progress.

Figure 5. Optimization, typical scenario, Atlantic region.