The STARE Project:  
A Progress Report

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Abstract.
The Survey for Transient Astronomical Radio Emission (STARE) is a wide-field monitor for transient radio emission at 611 MHz on timescales of fractions of a second to minutes. Consisting of multiple geographically separated total-power radiometers which measure the sky power every 0.125 sec, STARE has been in operation since March 1996. In its first seventeen months of operation, STARE collected data before, during, and after 173 gamma-ray bursts. Seven candidate astronomical radio bursts were detected within ±1 hr of a GRB, consistent with the rate of chance coincidences expected from the local radio interference rates. The STARE data are therefore consistent with an absence of radio counterparts appearing within ±1 hr of GRBs, with 5σ detection limits ranging from tens to hundreds of kJy. The strengths of STARE relative to other radio counterpart detection efforts are its large solid-angle and temporal coverage. These result in a large number of GRBs occurring in the STARE field of view, allowing studies that are statistical in nature. Such a broad approach may also be valuable if the GRBs are due to a heterogenous set of sources.

INTRODUCTION

The Survey for Transient Astronomical Radio Emission (STARE) is a project designed to detect transient radio signals at 611 MHz on timescales of fractions of a second to minutes. Local interference rejection is accomplished by using geographically separated multiple detectors and a coincidence requirement. STARE monitors a large solid angle 24 hours/day, with an operating efficiency of ~95%. We present here a brief description of the project and some of the results from the first 17 months of operation.

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INSTRUMENTATION

STARE consists of three detectors located at geographically separated sites: Hancock, NH, Green Bank, WV, and Hat Creek, CA. At each site is a total power radiometer, a GPS receiver which provides timing information, and a PC which controls the equipment. Operation is fully automated, and is coordinated over the internet by a computer at MIT, which also receives data from the sites. The organization of the system is shown in Figure 1.

The radiometers are simple single-conversion, dual-polarization receivers. System specifications:

- Center Frequency: 611 MHz
- Bandwidth: 4 MHz
- Beam Solid Angle: 1.5 sr
- Integration Time: 20µs to 0.125 s
- RMS Sensitivity: \( \sim 3 \text{kJy} \) (zenith, 0.125 s averaging)

TRANSIENT DETECTION BY COINCIDENCE REQUIREMENT

Radiofrequency interference (RFI) presents a major obstacle to transient detection at UHF. At these frequencies it is imperative that an experiment have an interference rejection scheme. STARE filters out RFI using a coincidence requirement. To be identified as astronomical, a signal must appear in at least two of the detectors simultaneously. The power of this criterion is apparent from the STARE results: in one year of operation, the Hancock station recorded 78,714 individual events (instances in which the radiometer output exceeded the baseline by at least 5\( \sigma \)) while the Green Bank station recorded 260,407. Out of these, only 138 coincidences were identified, yielding a rejection rate of well over 99%.

With such a scheme, there is always the possibility of coincidences due to chance. Using the mean event rates measured for Hancock (7 hr\(^{-1}\)) and Green Bank (13 hr\(^{-1}\)), the mean time between chance coincidences is found to be about 4 days, though the chance coincidence rate is quite variable since it depends on the (variable) underlying rates of RFI bursts at each site. Adding a third site with a rate identical to that of Green Bank increases the mean time between chance coincidences to about 27 years. For this reason STARE was designed to include three sites. The Hat Creek site, however, has been found to have an RFI environment unsuitable for general transient detection. Work is in progress to remedy this situation in order to give STARE the full interference rejection capability for which it was designed.
FIGURE 1. STARE System Organization
A strength of the STARE project in searching for GRB counterparts is that it monitors a large fraction of the sky nearly twenty-four hours per day. It will record from GRBs in its field of view any radio emission occurring after, during, or even before the GRB itself (with intensity above the STARE sensitivity level, of course). The price paid for a large field of view is lower sensitivity than that of a narrow-field detector. However, the large field of view also increases the number of GRBs expected to occur within the antenna beam.

STARE began multi-site operation on 26 March 1996 when the Green Bank station came on-line (Hancock came on-line in August 1995). Between that time and 31 August 1997, 173 GRBs (detected by BATSE) occurred in the field of view (above $20^\circ$ elevation) of at least one of the STARE sites. For each GRB, the STARE coincidence record was examined for detections within $\pm 1$ hr of the gamma-ray event. 7 positive results were found, which is consistent with the number expected from chance. None of the seven occurred simultaneously with a GRB. In addition, for each GRB, the raw STARE data record from each site was examined manually for unusual activity within $\pm 30$ min of the GRB. Nothing was found which was not obviously the usual RFI. We conclude that the STARE data are consistent with an absence of radio counterparts appearing within $\pm 1$ hr of GRBs, with $5\sigma$ detection limits ranging from tens to hundreds of kJy. A histogram of the ensemble of upper limits is shown in Figure 2.
FIGURE 2. Histogram of STARE flux density 5σ upper limits for 173 GRBs

(represents 4 upper limits ≥1000 kJy)