IB 95-91

DOCKET FILE COPY ORIGINAL

ORIGINAL

WILEY, REIN & FIELDING

1776 K STREET, N.W.
WASHINGTON, D.C. 20006
(202) 429-7000

EX PARTE OR LATE FILED

April 12, 1994

WRITER'S DIRECT DIAL NUMBER

(202) 429-7269

FACSIMILE
(202) 429-7049

RECEIVED
OCT 1 - 1996
FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF SECRETARY

Report
Not PCS

Mr. H. Franklin Wright, Chief
Frequency Liaison Branch
Federal Communications Commission
2025 M Street, NW Room 7102
Washington, D.C. 20554

re: CD Radio Experimental License, Call Sign K02XES

Dear Mr. Wright:

Satellite CD Radio, Inc. ("CD Radio") hereby files its experimental report for tests conducted under the above-captioned license.

If any questions arise concerning this report, please contact the undersigned.

Respectfully submitted,

Carl R. Frank
Counsel for Satellite CD Radio, Inc.

cc: FCC File PP-24

No. of Copies rec'd 2
List A B C D E

DAR MOBILE S-BAND EMULATION

Robert D. Briskman
CD Radio Inc., Washington, D.C.

ABSTRACT

A precise emulation of a new satellite radio direct broadcast service to subscriber automobiles has been performed. It utilized for the first time S-band frequencies, simulation of satellite transmission spatial, frequency and time diversity, and psychoacoustic compression of the CD stereo music by a factor of over eleven. The demonstration automobile was equipped with a micro-sized antenna for receiving 30 music channels. Measurement results showed the system avoids service outages from transmission path physical blockages and significantly reduces multipath fading.

INTRODUCTION

A geosynchronous satellite system capable of providing many channels of Digital Audio Radio Service (DARS) to mobile platforms within the contiguous United States using S-band radio frequencies is being implemented. The system is designed uniquely to mitigate both multipath fading and outages from physical blockage in the transmission path by use of satellite spatial diversity in combination with radio frequency and time diversity. Figure 1 shows the generalized system configuration. The system also employs a satellite orbital geometry wherein all mobile platforms in the contiguous United States have elevation angles greater than 20° to both of the diversity satellites. Since implementation of the satellite system will require three years, an emulation has been performed using terrestrial facilities in order to allow evaluation of DARS capabilities in advance of satellite system operations. The major objective of the emulation was to prove the feasibility of broadcasting from satellites 30 channels of CD quality programming using S-band frequencies to an automobile equipped with a small disk antenna. The paper describes the DARS satellite system, the emulation configuration and emulation performance results.

DARS SATELLITE SYSTEM

The satellite system consists of two geosynchronous satellites, one located over the east coast of the United States at 80° West Longitude and the second over the west coast of the United States at 110° West Longitude. The satellites receive in the 6720 MHz band and transmit in two 8 MHz segments of the 2310-2360 MHz band. The satellites each receive the same transmission from the system's up-link/programming center essentially simultaneously and retransmit the signal through an antenna beam covering the contiguous United States. Figure 2 shows the block diagram of the satellite's transmission payload. The retransmission frequencies of the two satellites are separated by 20 MHz and the beam edge EIRP is 57 dBW. The high EIRP is required due to the low gain of the mobile platform antenna. The transmission consists of 30 stereo CD music channels, a 128 kb/s service channel and several information channels. The CD stereo music channels are compressed prior to transmission using a joint encoding algorithm based on perceptual audio coding so only a 128 kb/s output data rate is required for each. The channels are digitally multiplexed together (i.e., TDM-time division multiplex) with interleaving in time, resulting in a 4 Mb/s output signal. The output signal is convolutionally encoded, a Reed-Solomon code added and then transmitted to the satellites using offset quadraphase shift keying.

The satellite retransmissions are received by the mobile platforms, particularly passenger automobiles. The mobile platform G/T at worst operational aspect angle is -19 dB/K. The antenna is designed to provide 3 dBi gain within a 20°-60° elevation angle range at all azimuths. The antenna is physically 2.5 cm in radius and 0.4 cm thick, designed for embedment in automobile rooftops. A photograph of the antenna is shown in Figure 3. After radio frequency reception, amplification and down conversion, the transmission from each satellite is individually demodulated. The two signals are time phased together using a maximal ratio combiner and then de-multiplexed. The user selects the specific music channel desired which is then routed to the decompressor, the digital-to-analog converter and the audio amplifier-loud speaker subsystem. Figure 4 shows a block diagram of the mobile platform receiver. The mobile platform receiver just described enjoys great resistance to multipath fading and blockage since its mechanization takes advantage of satellite spatial, frequency and time diversity as depicted in Figure 5.

EMULATION OBJECTIVES

There were many objectives of the emulation which was configured to simulate closely the previously described DARS satellite system. Among the more important ones were to:

1. Show that satellite spatial diversity significantly reduces transmission outages from blockages

2. Measure the reduction in multipath fading provided by satellite spatial and frequency diversity

3. Evaluate the mobile user environment including integration of the automobile receiver operation and display

4. Assess received music quality after psychoacoustic compression with a 128 kb/s output transmission rate

5. Search for interference sources in the 2310-2360 MHz band

EMULATION IMPLEMENTATION

It is difficult to emulate the capabilities of the previously described DARS satellite system using terrestrial facilities to simulate the satellites. This is because achieving a 20° elevation angle to the mobile platform from the terrestrial transmitter simulating the satellite over a reasonably large area requires buildings or towers of great height. Also, the demonstration of spatial diversity requires two transmitters covering the same geographical area resulting in the need for several transmitters. A satellite system emulation range was constructed in Northern Virginia close to Washington D.C. Figure 6 is a roadmap of the range. Five high-rise building tops were used as transmit locations to a vehicle driving a route through the area configured so that two transmit locations are always at 10° or more elevation angle from the vehicle, and only one transmit path at a time experiences physical blockage. The particular driving route included areas representing both urban and suburban environments as well as areas with trees and a roadway overpass.

The 30 CD music channels and service channel were generated at a programming/up-link earth station in Washington, D.C. using the compression, multiplexing and modulation described earlier. The uplink station transmitted the signal at Ku-band to the SBS-6 satellite which relayed the signal to standard VSATs on the high-rise building roofs. The VSAT received signal was translated by a stable frequency converter to the 2310-2360 MHz band and was then re-radiated using a small S-band transmitter and omni-directional antenna. The S-band EIRP was adjusted to equal that which would have been received at the mobile platforms from the previously described geosynchronous satellites over the nominal vehicle route. The standard passenger vehicle used for the emulation was outfitted with a prototype receiver electronically identical to those that would be used in the operational satellite system. A

small depression was made in the car roof, the antenna inserted and the roof area repainted to make the antenna invisible. The automobile radio was modified with a single button to select Satellite Radio in addition to AM and FM, and an expanded display was used to show the driver the music composition name and composer being played on the CD channel selected. A photograph of the display is shown in Figure 7.

EMULATION OPERATIONS

An application was submitted to the FCC in December 1992 for an Experimental License to conduct the previously described emulation using rooftop mounted transmitters in the 2310-2360 MHz radio frequency band. The license was granted on February 25, 1993 and the measurements subsequently cited were performed primarily from April 1993 through early January 1994.

A simplified block diagram of the system used for the emulation is shown in Figure 8. Note that the automobile used a four channel receiver, rather than the two to be used in the actual DARS satellite system, to avoid self interference from the relatively closely spaced rooftop antennas and that the 30 music channels were compressed individually and then multiplexed. Twenty minute music segments were then placed on the computer disk at the up-link earth station for transmission during the demonstration. The music segments would repeat automatically at the end of the twenty minutes.

MEASUREMENT RESULTS

Some selected measurements of interest are presented. Figures 9, 10 and 11 show that no blockage occurred at measuring points around the driving range. At least one receiver channel always had a signal above threshold. Observation of multipath indicated that greater than 10 dB improvement was obtained from diversity and particular note is made of the 20 dB of frequency selective fading avoidance by diversity shown in Figure 12. A special test of blockage avoidance was made on one of the largest freeway overpasses in the Washington, DC area, and the measurements are summarized in Figure 13. The measurements show that no blockage outage would occur in vehicles passing under the overpass with the diversity satellite DARS system for the geometry utilized but would always occur for a single satellite DARS system.

Measurements of external radio interference in the 2310-2360 MHz frequency band showed no interference for the observing times and locations monitored. The music compression subsystem used was built by AT&T employing perceptual transform coding operating with

an output data rate of 128 kb/s. CD quality of the music was achieved as measured in AT&T laboratory tests; the music quality measurements in the automobile were subjective with observers rating the quality as excellent. The automobile used for the emulation was a Lincoln Mark VII. The radio was modified with the assistance of the Ford Electronics Division to have the capabilities shown in Figure 4 and to be operated by the driver with a single button control and with an extended display as shown in Figure 7. Post operations reviews indicated drivers highly rated the control simplicity and the display which showed various information on the music being played. Over two hundred engineering/operation runs have been performed to date with one quarter of the runs carrying evaluation participants.

SUMMARY

The emulation has accomplished its previously described objectives. From an operational viewpoint, emulation participants praised the transmission quality, the ease of vehicle radio operation and the equipment design. From an engineering viewpoint, considerable data were obtained on equipment and transmission performance. The transmission data showed that the combined spatial, frequency and time diversity provided large mitigation against multipath (greater than 10 dB) and avoidance of outages from blockage for the test range utilized.

Figure 1 -- The CD Radio System

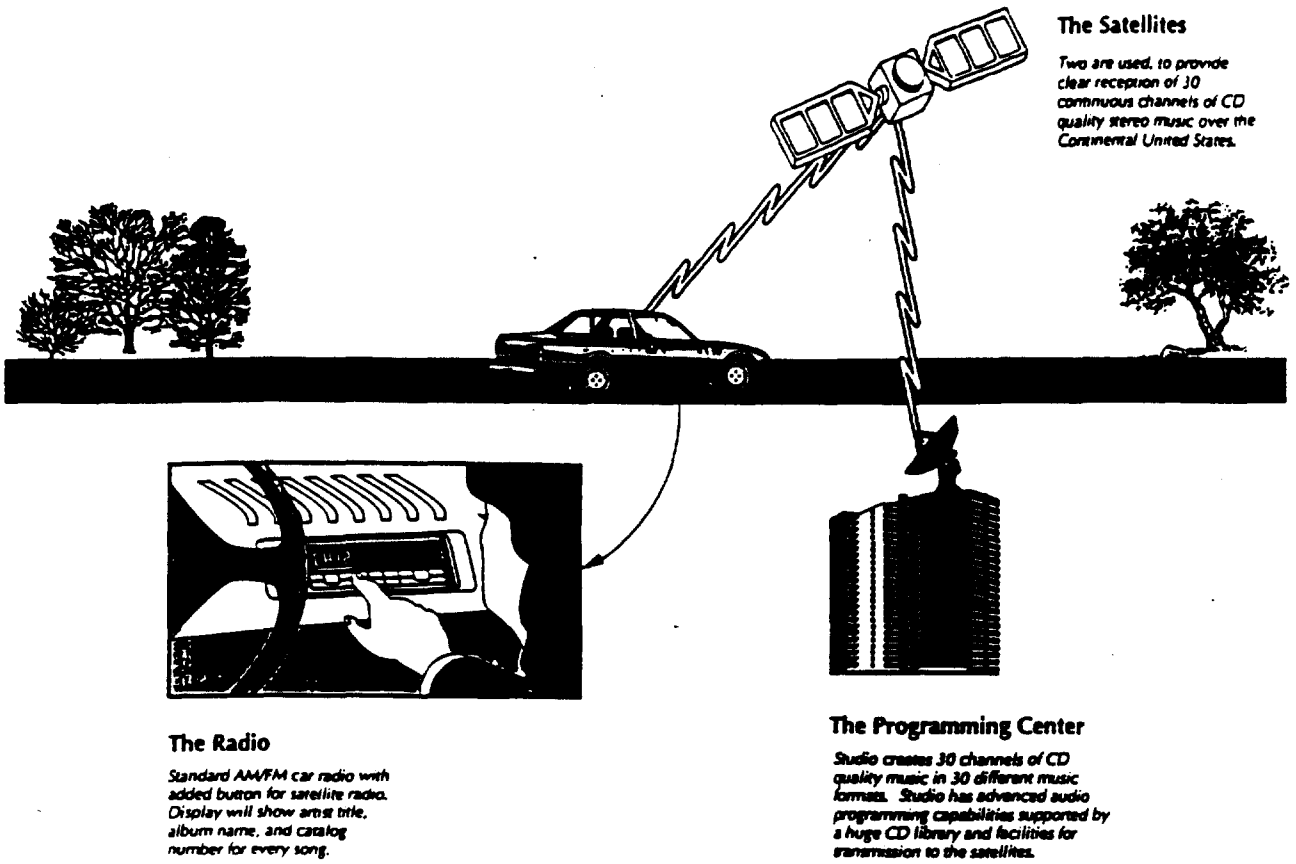

Figure 2 -- CD Radio Satellite Communications Block Diagram

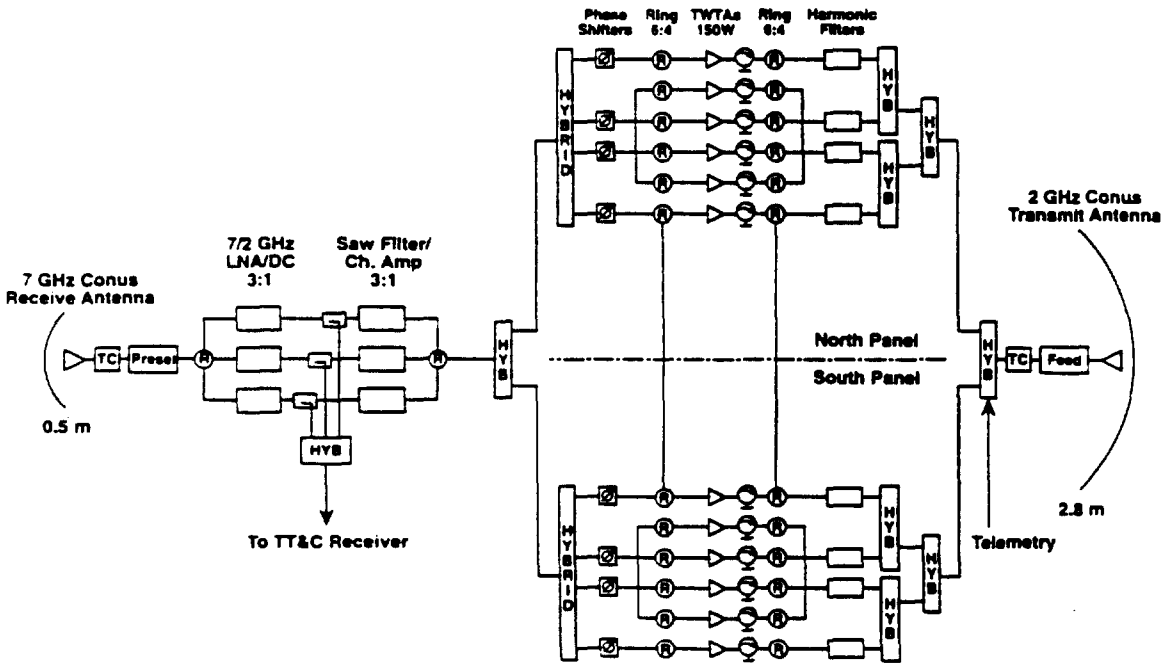

Figure 3 -- CD Radio Antenna

Figure 4 -- Vehicle Receiver
Analog AM & FM/Digital Satellite & Terrestrial

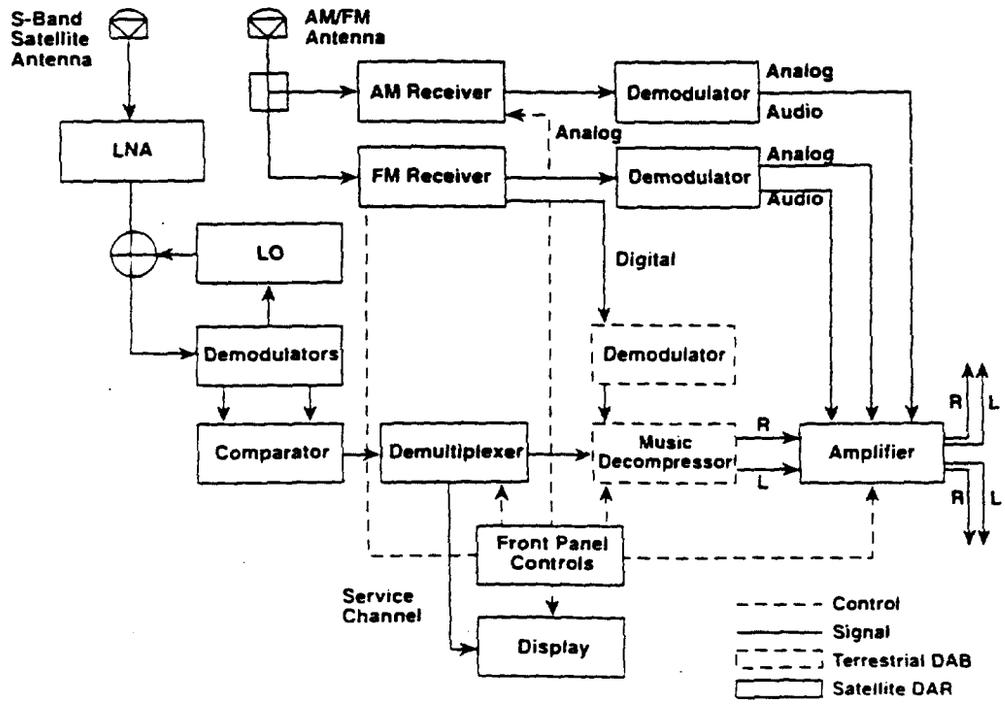

Figure 5 -- Reduction of Blockage Outages*
By Use of Two Radio Broadcast Satellites

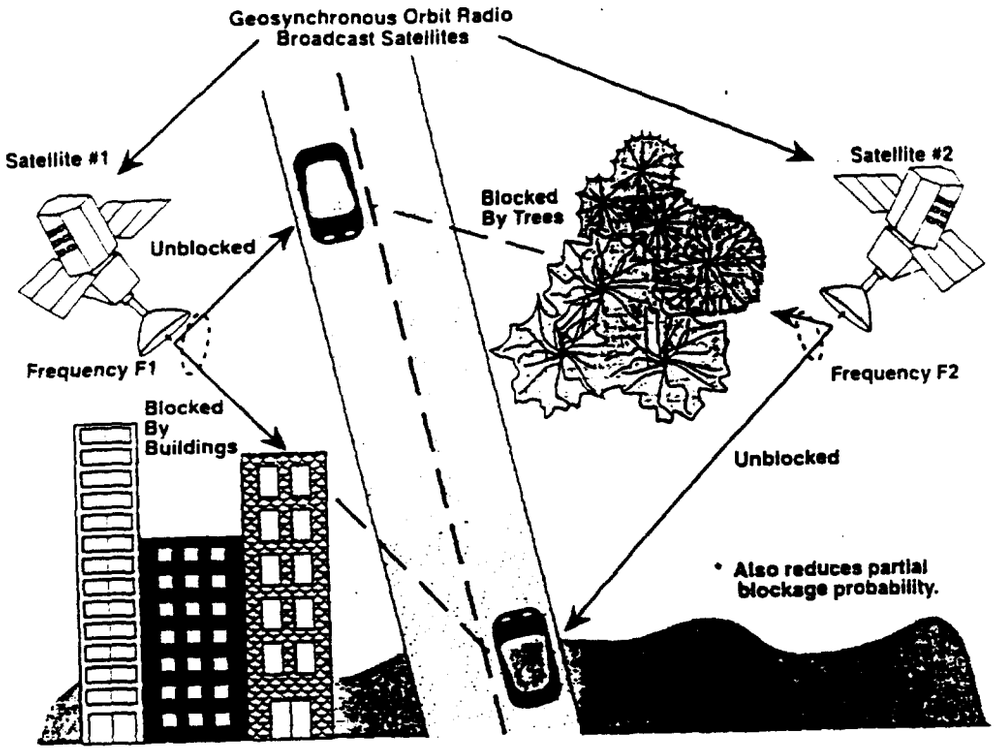

Figure 6 -- Test Range Road Map

Note: The test range is in Arlington, Virginia, part of metropolitan Washington, D.C.

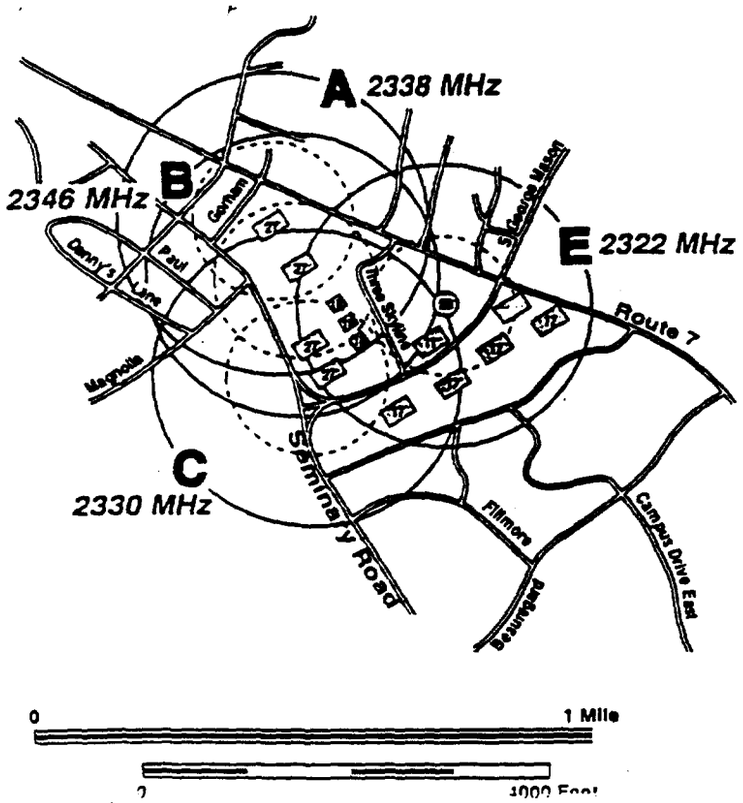

Figure 7 -- Car Radio Display

Figure 8 -- CD Radio Test System - Block Diagram

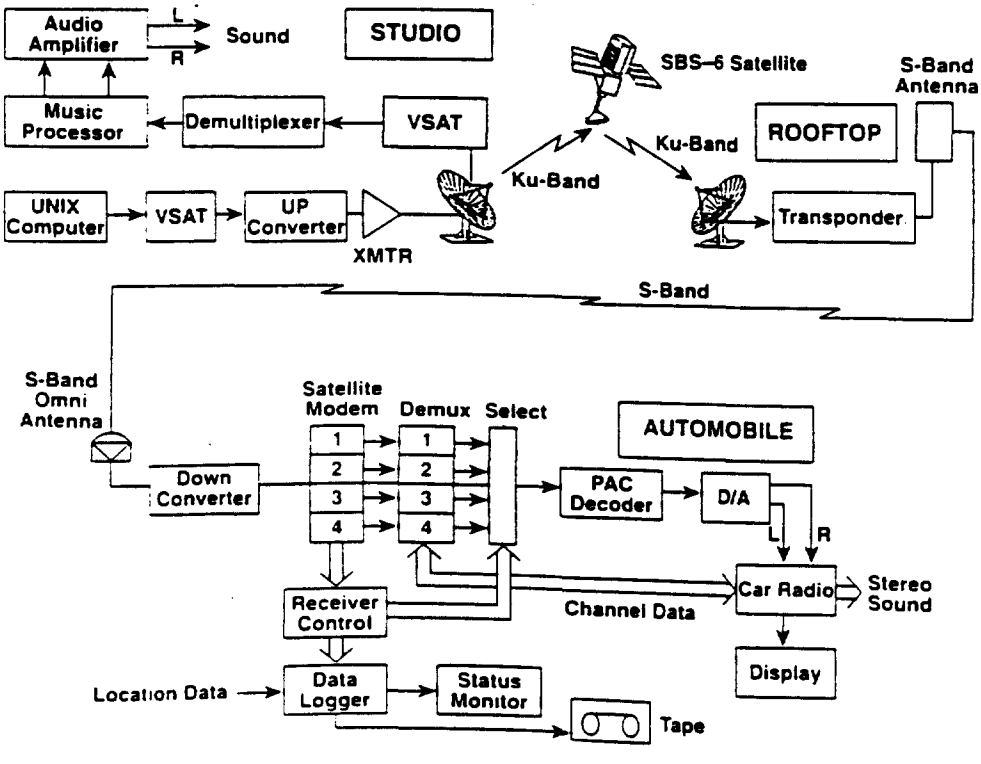

Figure 9 -- Test Range Measurement Points

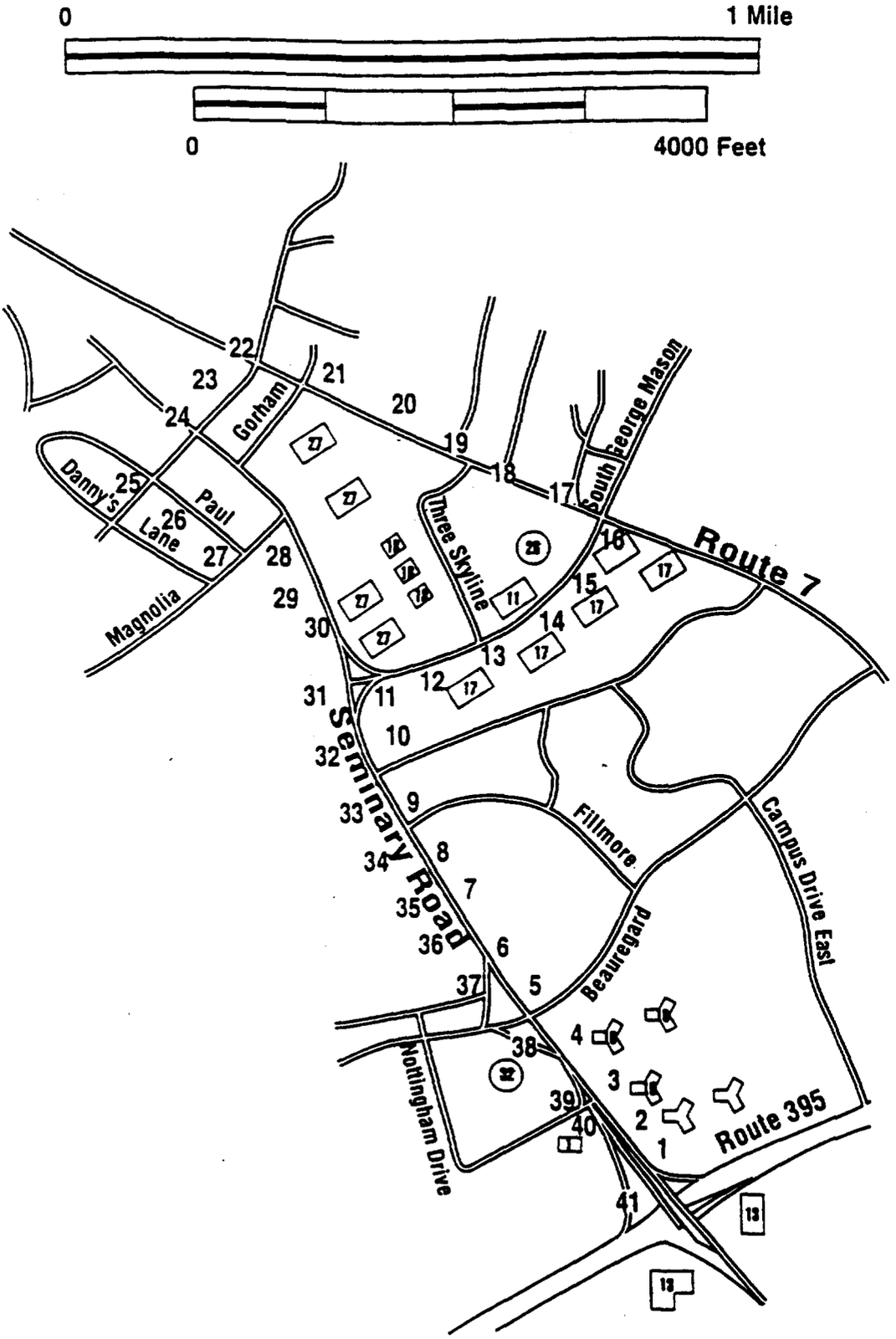

Figure 10 -- Test Range AGC Measurements - Sheet 1 of 2

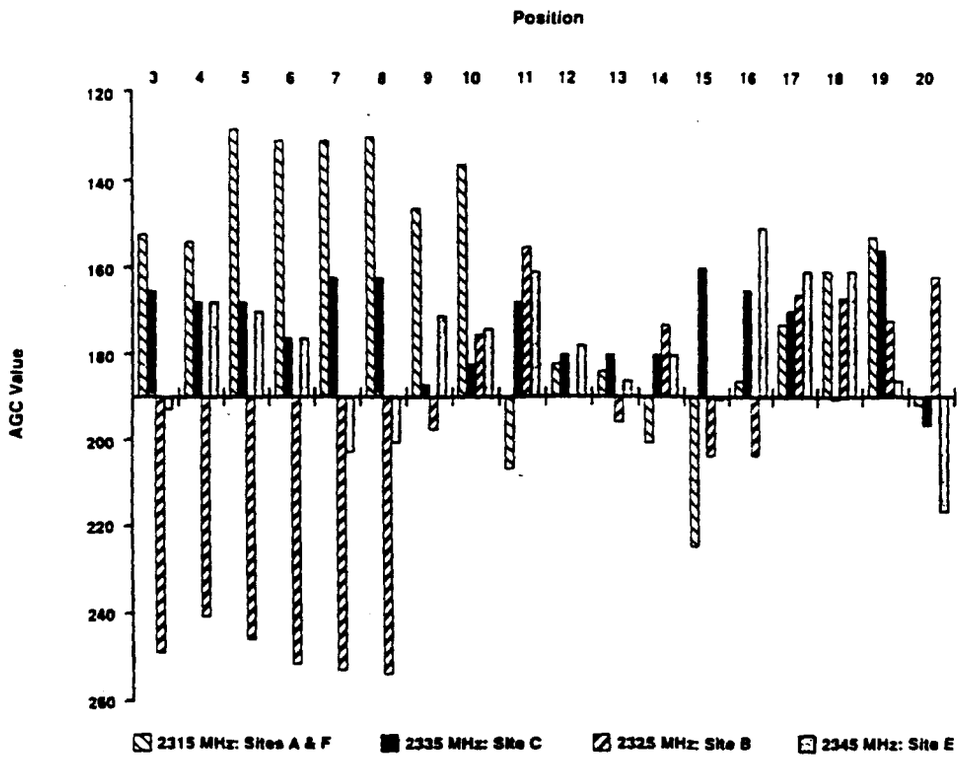

Figure 11 -- Test Range AGC Measurements - Sheet 2 of 2

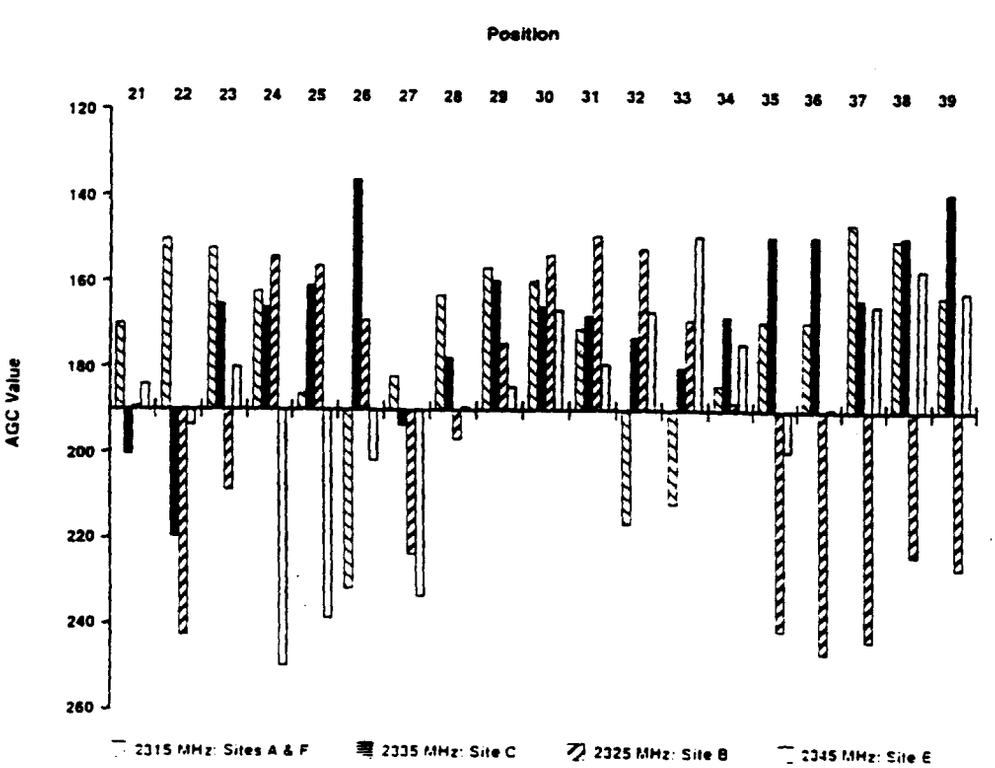

Figure 12 -- Test Range Spectrum Plot

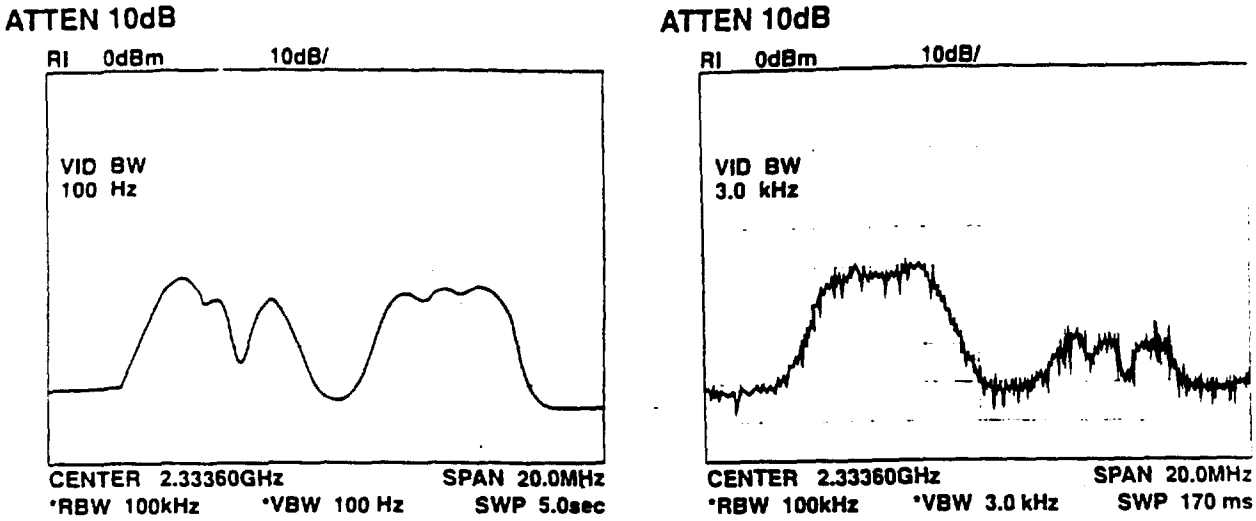
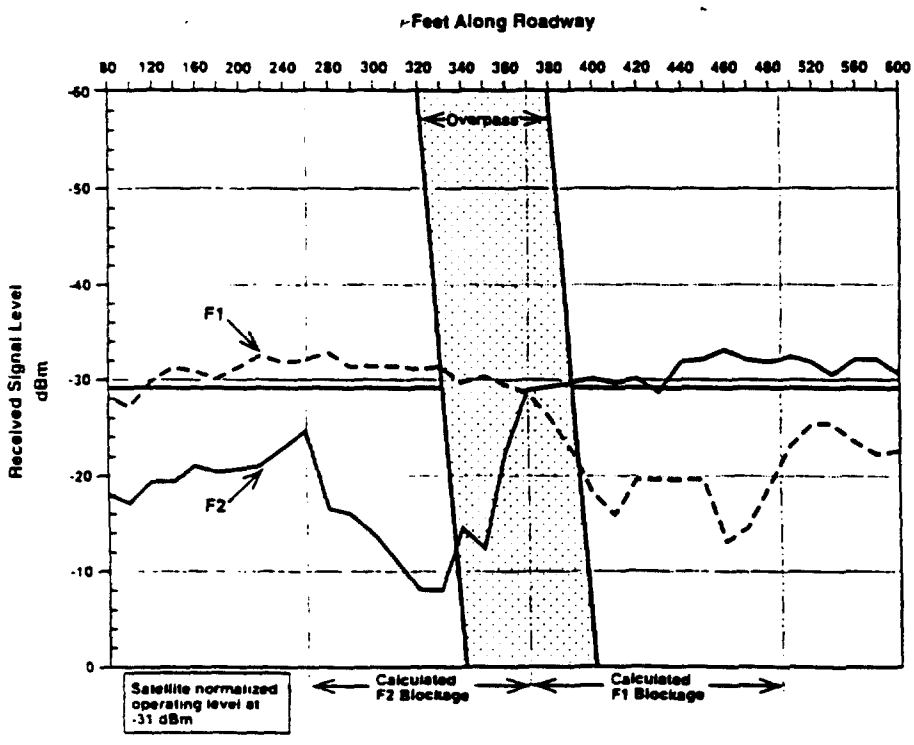
Figure 13 -- Highway Overpass, Test Results Summary