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FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF SECRETARY

William Caton, Acting Secretary
Federal Communications Commission
1919 M Street, NW Room 222
Washington,, D.C. 20554

Re: PP-24, Experimental License KO2XES

Dear Mr. Caton:

Pursuant to Section 5.204 of the Commission's Rules, 47 C.F.R. § 5.204 (1994), attached is the most recent experimental report showing the progress of CD Radio Inc. testing and experimentation in connection with its experimental license and pending application for pioneer's preference. The report covers recent use of an S-Band satellite (NASA TDRS) to characterize the satellite-to-mobile path in the digital audio radio service (DARS). In particular, the experimentation was designed to determine the extent to which blockage, shadowing and multipath conditions created polarization reversal in the received signal.

If there are any questions about the foregoing, please contact the undersigned.

Sincerely,

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

Attachment
cc: Rodney Small

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List A B C D E

NASA and CD Radio's TDRSS Industrial Test Program

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ABSTRACT

The National Aeronautics and Space Administration (NASA) has embarked on a joint test program with CD Radio Inc. The program will demonstrate spatial diversity techniques in support of industrial development of a new satellite direct-broadcast national radio service called Satellite Radio. Satellite Radio will operate in the FCC approved frequency band 2310-2360 MHz which is close to NASA's Tracking and Data Relay System (TDRSS) satellites' high power transmit frequency near 2110 MHz. The cooperative test program in which NASA provides use of a TDRSS satellite and CD Radio provides the measurement equipped vehicle is described as well as its current status. Some initial measurement data are presented.

INTRODUCTION

Direct broadcast of radio programming from satellites to listeners in mobile vehicles, primarily automobiles and trucks, and in homes will be available before the end of the century. The service is called Satellite Radio and will operate in the Federal Communications Commission's approved frequency band 2310-2360 MHz. The service will provide listeners with diversity of radio programming, particularly in rural areas; niche programming, including foreign language and ethnic channels; and educational and cultural opportunities on a nationwide basis. Technical development, manufacturing and industrial benefits are also foreseen. Providing high quality Satellite Radio service to mobile vehicles requires that service outages, which are primarily caused by multipath and physical blockage be made extremely infrequent. CD Radio intends to accomplish this by use of satellite spatial diversity in conjunction with other outage mitigation methods. Additional measured data on satellite spatial diversity at S-band frequencies would be useful, and a cooperative program with the National Aeronautics and Space Administration (NASA) was derived using the government's Tracking and Data Relay Satellite System, whose satellites can transmit with reasonable power at S-band (approximately 2110 MHz). The industrial test program is described in the following material.

SYSTEM/EXPERIMENT DESCRIPTION

The long range program is the accumulation of data on satellite spatial diversity performance for mobile reception in automobiles over a wide range of environments and conditions. This includes the various terrains throughout the country, operation in suburban/urban areas, effects of elevation angle to the satellites, and of trees, etc. The data will take the form of service outage occurrences and the length of such occurrences as a function of the previously mentioned conditions. The duration of the experiment is expected to be lengthy for several reasons, one of which is that measurements can only be performed when the TDRSS satellites are not being used for government purposes or for other experiments and as a function of the satellites' orbital locations.

The first phase of the experiment program has been initiated and will be described in the following material. The objective of the first phase was to characterize precisely the TDRS-to-automobile path in a mobile environment. The goal is to obtain field strength and polarization characteristics of the path over the eastern half of the contiguous United States. This can be done from the TDRS-East at elevation angles of interest (i.e., 20°-35°).

The measurement system utilizes a NASA

uplink which generates a Ka-band carrier to the TDRSS satellite sufficient to saturate the satellite's S-band transmitter. NASA also positions the satellite antenna beam to the portion of the eastern half of the U.S. where measurements are to be made that day. The S-band carrier is transmitted from the satellite using right hand circular polarization (RHCP). The measurement vehicle was developed, instrumented and operated by CD Radio. It is a passenger automobile with an instrument pod mounted on the roof containing a RHCP receiving antenna, a LHCP receiving antenna, and a Global Positioning System (GPS) antenna with the preamplifiers, detectors and a data acquisition system inside the car. Figure 1 is a simplified system depiction and Figure 2 shows a typical TDRS satellite downlink antenna coverage. Essentially, the amplitude of the received right and left hand polarized satellite transmissions are measured as a function of the automobiles physical location and time.

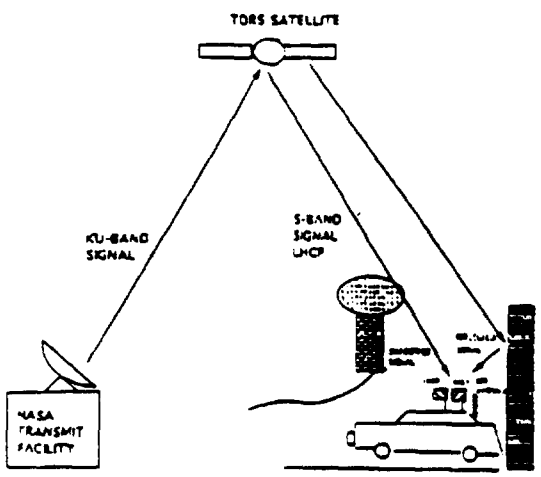

Figure 1 - System Configuration

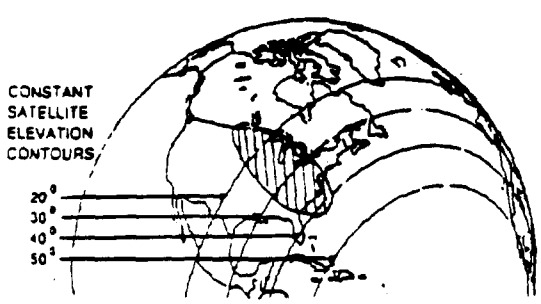

Figure 2 - S-Band Beam from TDRS at 45 Degress West

The link budget is based on a satellite beam center EIRP of 46.4 dBW (i.e., a flux density of -116 dBW/m²/4kHz). A nominal path loss of -190.5 dB, a receiving beam center car antenna gain of 3.5 dBi and losses of 1.2 dB result in a received power of -141.8 dBW. The receiver noise power in its 1 kHz detection bandwidth is -176.3 dBW. Assuming good measurement precision at a C/N of 8 dB and averaging over 200 samples, fading of 26 dB can be accurately measured. The TDRS antenna's maximum axial ratio over the 3 dB beamwidth is 1.5 dB and the automobile antennas are similarly specified. An axial ratio of 1.5 dB reflects a cross-polarization rejection of 21 dB. However, since most measurements were made closer to beam center where axial ratios are better, the total polarization isolation is estimated as 25 dB ± 5 dB.

The following sections describe in more detail the space segment, the measurement vehicle and early measurement results.

SPACE SEGMENT

The NASA/CD Radio TDRSS Industrial Test program is based upon the Space Act of 1958 (42 U.S.C. 2451 et seq.) sections 203(c)(5)and 203(c)(6) and as implemented by NASA Management Instruction (NMI)1050.9A. The purpose of the Space Act Agreement is to conduct joint experimental programs between NASA and U.S. Industry for public benefit, U.S. manufacturing and obtaining technical data and development. There are two general types of Space Act Agreements called for (1) Reimbursable and (2) Non- Reimbursable.

NASA's Space Act Agreement with CD Radio is Non-Reimbursable and calls for the obtaining of technical data regarding satellite reception of digital audio radio at S-band on mobile platforms. The experimental program includes the testing of polarization isolation, diversity reception techniques and advanced automobile antennas at S-band.

The NASA satellite constellation that is being used for the CD Radio Industrial Test is the Tracking and Data Relay Satellite System (TDRSS) as shown in Fig.3. This system operates at both S-band (2025-2300 MHz) and at Ku-band (13.7-15.3 GHz). Single-access services in the S-band and Ku-band ranges use the umbrella-shaped, steerable 4.9-meter parabolic dish antennas to communicate with one user at a time. Operating in the S-band and Ku-band frequencies, the TDRSS can handle up to 300 million bits of information each second from a user, the

equivalent of the material in a 20 volume encyclopedia.

Tracking and Data Relay Satellites communications is controlled from two ground terminals located at White Sands, New Mexico. This site was chosen for its low geographic latitude within the United States, affording a clear view of the satellites, and because service interference caused by weather was minimal. The terminals are responsible for maintaining such functions as transmitting commands to the spacecraft, receiving the user data returned through each TDRSS, and keeping track of system status.

Under normal operations all uplink and downlink communications between a TDRSS satellite and the Earth (White Sands, NM) pass through the satellite's 2-meter parabolic dish antenna near the hexagonal satellite body. The NASA/CD Radio Test Program utilizes the same White Sands Uplink but uses the 4.9 meter parabolic dish antenna to transmit digital audio signals to the test vehicle on the ground see Fig 1.

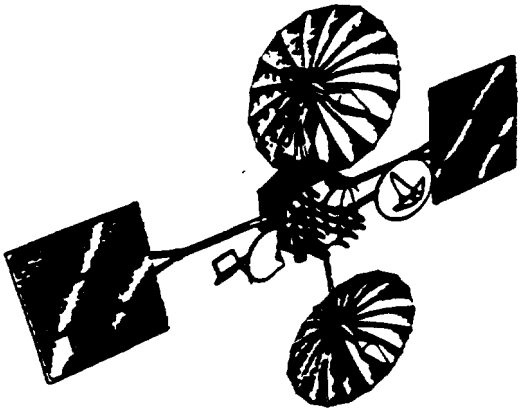

Figure 3 - Tracking and Data Relay Satellite System (TDRSS)

EARTH SEGMENT

The automobile used for the initial measurement phase is shown in Fig. 4 and its equipment block diagram in Fig.5. The LHCP and RHCP antennas are quadrifilar helices. The instrument pod contains microwave S-band absorber material to prevent reflection from the automobile rooftop from affecting the transmission path characterization. The data acquisition computer records the data in blocks, each block having a time stamp (6 bytes), vehicle location, speed and compass heading from the GPS (17 bytes) and the two signal amplitudes (4 bytes). An additional field is to be added allowing vehicle operator insertion of terrain/environment codes. By use of the vehicle tire rotation detector, it is possible to measure data only when the vehicle is in motion. Various equipment calibration and self-test features have been incorporated particularly to keep the receiving system gain, noise temperature and center frequency within required tolerance.

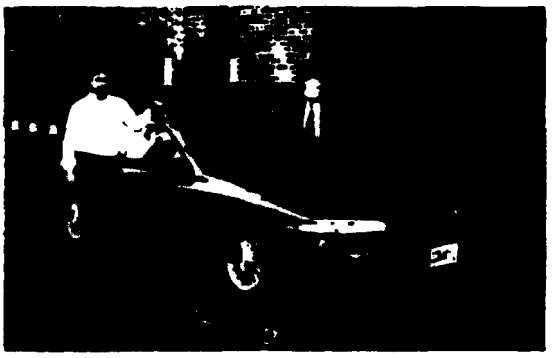

Figure 4 - Measurement Automobile

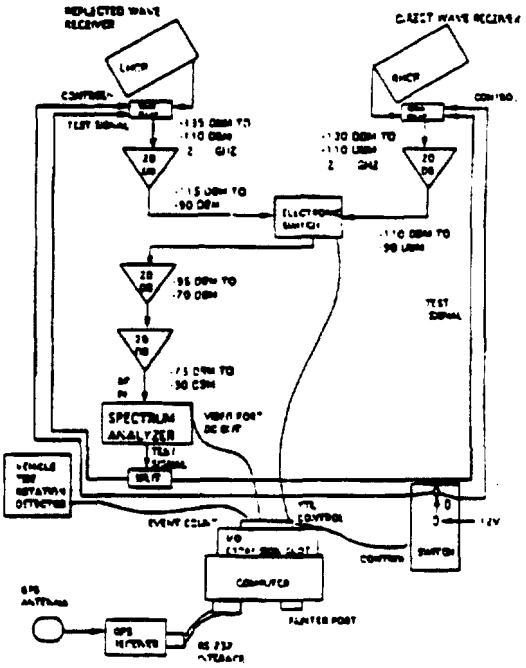

Figure 5 - Test Receiver

EARLY MEASUREMENTS

Several measurement sessions were conducted late last year. The initial one was static for equipment performance and calibration. This was followed by short mobile measurements both to characterize equipment performance in the automobile and to make routine the TDRS scheduling by the NASA Goddard Space Flight Center (GSFC). These tests detected leakage paths in the automobile measuring equipment which were rectified by additional shielding and changes in cable runs and minor software defects. The scheduling by GSFC was handled in an extremely efficient and professional manner. As earlier mentioned, besides finding convenient holes in the busy TDRS schedule, GSFC provides the up-link satellite signal and frequency clearance of the high flux density TDRS down link signal so no interference is caused to other government users of this radio frequency.

Two long duration measurement runs were made on October 30 and 31, 1994 each of several hours. Many hundreds of kilometers were covered including areas of downtown Washington, DC, suburban Virginia and rural Virginia. Data points were measured every 1.5 meters of vehicle movement. A plot of the measured data is shown in Fig. 6 for a rural area with no blockage over a 14 minute period. Fig. 7 is similar for an urban area with blockage and shadowing. The direct signal at the input of the measuring device averaged -70 dBW ± 0.5 dB and the cross polarized signal averaged -95 dBW ± 5 dB. The cross polarized received signal consists of the components caused by the lack of perfect polarization circularity (i.e., axial ratio) of the TDRS and automobile antennas, specular reflection where the polarization sense becomes reversed and residual noise from diffuse scattering and the noise floor of the automobile receiver.

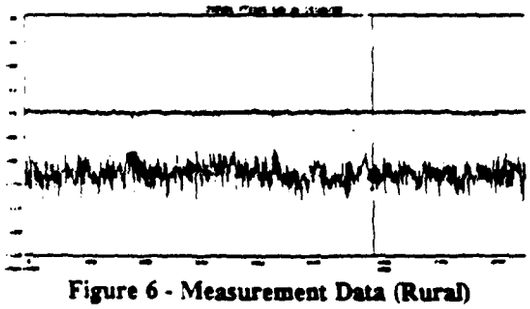

Figure 6 - Measurement Data (Rural)

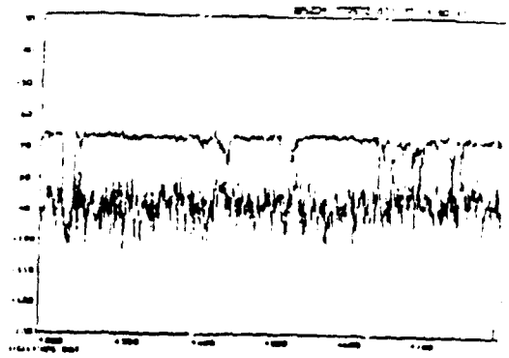

Figure 7 - Measurement Data (Urban)

Preliminary partial analysis of the data indicates relatively few occasions that a significant cross polarization component occurs under non-blockage/shadowing conditions of the direct signal. Significant is meant herein as where the cross polarized component is -12 dB or more with respect to the direct signal. This implies that few non-blocking specular reflections with polarization reversal occur for this satellite elevation angle and ground environment. Conversely, most of the time when the direct signal is blocked or heavily shadowed (attenuated 15 dB or more), the cross polarization component is significant. This implies that specular reflections with polarization reversal occur in blockage or heavily shadowed conditions. This is supported by the fact that the significant cross polarization components are generally of short duration.

SUMMARY

At the conclusion of testing, CD Radio will reduce the data obtained and issue a formal report summarizing the results of the testing. Copies of this report will be made available to NASA and the Federal Communications Commission. This type of cooperative government industry test program has been initiated by NASA and CD Radio Inc. to derive useful data on satellite spatial diversity in connection with the development of a new broadcasting service in the United States which will benefit the public, technology development and manufacturing.