HOW GEOSTAR RADIODETERMINATION TECHNOLOGY MINIMIZES INTERFERENCE TO RADIOASTRONOMY

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INTRODUCTION

Geostar Radiodetermination Satellite Service (RDSS) measures the position of vehicles on the earth using geostationary satellites and time-difference ranging techniques. One of the RDSS frequency bands overlaps with a radio astronomy frequency allocation. The Federal Communications Commission (FCC) mandated a unique spacetime frequency sharing rule to minimize interference.

OVERVIEW OF RDSS

RDSS works by maintaining and manipulating a continuous flow of information between a system control center, geosynchronous satellites, and user terminals called transceivers. The system control center transmits an interrogation signal, at 6533 MHz, many times per second to one of three geosynchronous satellites located 35,000 kilometers above the equator. This satellite retransmits that signal at 2492 MHz to a coverage area on the surface of the earth. The population of user transceivers receives the signal, and individual transceivers transmit a response at 1618 MHz if (a) the user desires a position determination or wishes to send a message, or (b) the signal contains information addressed to that transceiver.

The responses of individual transceivers are received by all three geosynchronous satellites and are retransmitted at 5183 MHz frequency to the system control center. Due to the varying distances between a user and each of the three satellites, as well as to the constant speed (velocity of light) at which the signals travel, the control center will receive three identical responses at slightly different times for each response of an individual transceiver.

A computer measures round-trip signal transit time by comparing a stored replica of the transceiver's emitted signal with the received signals, then measuring the associated time delay. This time delay, scaled by the velocity of light, is the measurement of the round-trip range from the system control center to the individual transceiver. The round-trip range measurement is converted to three-dimensional coordinates such as latitude, longitude, and altitude.

These position coordinates are then embedded in the continuous interrogation signal sent out to one of the three satellites for retransmission to the earth coverage area. Individual transceivers extract from this interrogation signal those coordinates that are addressed to their ID code. The transceiver then emits a further response to provide the system control center with an acknowledgement that it has received the position coordinates. If the system control center fails to receive the acknowledgement after a period of time, the coordinates are sent again.

RELATIONSHIP TO RADIO ASTRONOMY

Radio astronomy is a passive radio service in which scientists use ultra sensitive antennas to listen to radio emissions at particular frequency bands from various parts of the universe. The frequency bands required for spectral line observations are dictated by physical processes such as atomic transition levels, two of which (for the hydroxyl radical) fall within the 1.6 GHz region. In particular, radio astronomers use the 1606-1613.9 MHz band, which falls within the 1610-1626.5 MHz band used for RDSS. Due to the extreme sensitivities required by radio astronomy receivers, it is not possible to perform observations of the hydroxyl line at the same time that a transmitting RDSS user is within the line of sight of an observatory. In order to protect these valuable observations, a plan has been developed for coordinating RDSS and radio astronomy usage of the 1610 MHz region.

FCC REVIEW OF RDSS IMPACT

The FCC, in its Notice of Proposed Rulemaking for RDSS, commented that the 1610.6-1613.8 MHz band is used by the radio astronomy service for observing the hydroxyl spectral line. The FCC also noted that international radio regulations warn that emissions from airborne stations can be especially serious sources of interference for radio astronomy observations.

Geostar observed in its comments to the FCC that because of its unique technology, sharing with the Radio Astronomy service could be feasible. Although the "Table of Frequency Allocations" allocates the 1610.6-1613.8 MHz band to the Radio Astronomy service on a secondary basis, Geostar recognized that "in making assignments to stations of other services to which the band is allocated, administrations are urged to take all practicable steps to protect the radio astronomy service from harmful interference." In addition, the National Academy of Sciences (NAS) requested, at that time, a primary allocation of the 1606.8-1613.8 MHz band. Geostar noted that adoption of a spread spectrum random access TDM system design as a standard for the RDSS, together with strict rules restricting the time and space that RDSS occupies the 1610 MHz region, allows the United States to meet the requirements of the international Table of Frequency Allocations in good faith. This enables RDSS and the radio astronomy service to coexist in the band through coordinated operations. A specific technical arrangement was described by Geostar and the Committee on Radio Frequencies of the National Academy of Sciences in proposed RDSS rules.

The proposed rules were developed by Geostar and NAS to permit use of the RDSS within regions where radio astronomy observations were made. In brief, RDSS licensees would restrict their transmissions to occur within the first

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200 milliseconds following the one second time marks of Coordinated Universal Time when users enter Radio Astronomy Regions during a period of radio astronomy observations in the 1606.8-1613.8 MHz band. The spread spectrum TDM design makes it possible to both accurately determine the location of RDSS users and to constrain their time domain occupancy. Further, NAS and Geostar reached an agreement on an emission limitation for out-of-band radiation. NAS wanted the limitation applied to terrestrial and airborne vehicles and spacecraft, excluding only pedestrian "hand-held" units. However, Geostar felt that the requirement to extend this limitation to ground-based vehicular users would add an additional regulatory burden that would increase transceiver costs and is unnecessary to protect radio astronomy observations.

SPECIFIC SHARING ARRANGEMENT AT 1.6 MHz

The radio astronomy and RDSS sharing plan has been adopted as law in the United States. The law provides as follows:

(1) All Radiodetermination Satellite Service licensees will automatically restrict transmission to occur only within the first 200 milliseconds following the one-second time marks of Coordinated Universal Time when users enter Radio Astronomy Regions during a period of radio astronomy observations in the 1606.8-1616.8 MHz band. Any segment of a Radio Astronomy Region that is part of a Consolidated Metropolitan Area is not subject to coordination and transmission restriction limitations.

(2) Each Radiodetermination Satellite Service licensee will establish an observation notification procedure through the Electromagnetic Spectrum Management Unit, National Science Foundation, that satisfactorily provides for the restriction of user transmissions as described above during periods of radio astronomy observations in the frequency band 1606.8-1613 MHz.

Radio Astronomy Regions are defined as regions centered on certain major observatories with a radius of 150 km in the air and 25 km on the ground. An effect of these coordination restrictions is to increase slightly the response time to user transmissions because the transmissions can occur only within certain periods of time. A second effect is to increase the integration time for radio astronomy observations of the hydroxyl line. These restrictions, however, permit two apparently incompatible services to utilize the same frequency band with acceptable operational complexities.

IMPACT OF RDSS ON OTHER RADIO ASTRONOMY BANDS

A further problem between RDSS and radio astronomy involves the spectral distribution characteristics of spread-spectrum transmissions.

Spread-spectrum modulated transmissions, by their very nature, occupy an expansive amount of bandwidth at very low power densities. This causes no problems for most radio services, but can be highly pollutive toward the ultrasensitive radio astronomy service.

The unfiltered output of a transmitter with square-wave phase modulation has a very broad spectrum, described by $P_f = (\sin x/x)^2$, where $x = \pi(f-fo)/fc$, fo is the center frequency and fc is the chip rate of the modulation. In the particular

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case of a standard 8 Mcps rate, the sidebands would fall to an acceptable level of 38 dB below the peak power density of the transmitted signal at a frequency separation of 200 MHz from the center frequency. This very large separation would cause problems in a number of different radio astronomy bands, including the treasured 1400-1427 MHz band. Even more distressing to the radio astronomy community is that such distant out-of-band interference can be caused at a separation of hundreds of kilometers if the RDSS transceiver is airborne.

Accordingly, the following out-of-band emission limit was adopted to protect radioastronomy in the band 1606.8-1613.8 MHz: the mean power density of airborne and spacecraft RDSS emissions at a frequency which is removed from the assigned frequency by more than 50% shall be attenuated below the mean power density at the assigned center frequency as specified in the following equation (attenuation greater than 75 decibels is not required):

$$A = 12 + 0.2\,(P - 50)$$

where, A = attenuation (in decibels) below the mean power density level, and P = percent of assigned bandwidth removed from the carrier frequency.

CONCLUSION

The frequency sharing principles underlying the Geostar-NAS Agreement are unlikely to serve as a basis for other sharing arrangements between scientific and commercial uses of the radio spectrum. The reason for this is that its success depends uniquely on the burst-mode TDM transmission architecture of Geostar. The sharing arrangement would not be practical for telecommunication systems which require continuous channel occupancy, such as for voice applications. Accordingly, RDSS/Radio Astronomy sharing should probably be viewed as "the exception which proves the rule" that passive and active services cannot usefully employ the same spectrum.