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Modeling C-Band Co-Channel Interference From AeroMACS Omni-Directional Antennas to Mobile Satellite Service Feeder Uplinks

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Summary

A new C-band (5091 to 5150 MHz) airport communications system designated as Aeronautical Mobile Airport Communications System (AeroMACS) is being planned under the Federal Aviation Administration's NextGen program. An interference analysis software program, Visualyse Professional (Transfinite Systems Ltd), is being utilized to provide guidelines on limitations for AeroMACS transmitters to avoid interference with other systems. A scenario consisting of a single omni-directional transmitting antenna at each of the major contiguous United States airports is modeled and the steps required to build the model are reported. The results are shown to agree very well with a previous study.

1.0   Introduction

Aeronautical Mobile Airport Communications System (AeroMACS) is a new C-band (5091 to 5150 MHz) airport communications system being planned under the Federal Aviation Administration's NextGen program (Ref. 1). Radio Technical Commission for Aeronautics (RTCA) Special Committee 223 is now engaged in defining standards for the AeroMACS service in the United States. European Organization for Civil Aviation Equipment (EUROCAE) Working Group 82 is conducting a parallel activity in Europe. It is essential that significant interference with other C-band systems already occupying the band does not occur. Services for which approved allocations now exist in the 5091 to 5150 MHz band include Aeronautical Radionavigation Service (ARNS), Aeronautical Mobile Service (AMS) (specifically Aeronautical Security (AS)), Aeronautical Mobile Telemetry (AMT), Aeronautical Mobile (Route) Service (AM(R)S), and Fixed Satellite Service (FSS) (specifically Mobile Satellite Service (MSS) feeder uplink). The Globalstar low Earth orbit (LEO) constellation is currently using the FSS service allocation in this band. The other services allocated in this band are not yet being used. At the same time, the AeroMACS system will operate as AM(R)S, with a higher priority than the other services allocated except the incumbent FSS system. Hence, the issue of primary and immediate interest is interference from AeroMACS into the FSS, specifically the MSS feeder uplink. The ultimate goal of this effort is to enable the establishment of practical limits on AeroMACS transmissions from airports so that the threshold of interference into MSS is not exceeded. The limits thus established will be used in the RTCA standards development process.

2.0   Analysis

In this interference modeling of a simplified AeroMACS architecture, Visualyse Professional Version 7 software from Transfinite Systems Limited (United Kingdom) (Ref. 2) is utilized. In order to benchmark the software, the architecture configuration of a case from Hoh, Gheorghisor and Box (Ref. 3) is used in the model and the results compared. In Reference 3, the co-channel interference from an Airport Network and Location Equipment (ANLE/now referred to as AeroMACS) system to non-geostationary mobile-satellite-service (MSS) feeder uplinks was analyzed. It was assumed that there was

one transmitter with an omni-directional antenna at each of 497 major airports in the contiguous United States. A worst case scenario was modeled with all transmitters on 100 percent of the time.

In the model, each airport transmitting antenna contributes the interference power P_r at the LEO, 1414 km above the surface:

$$P_r(\text{dBW}) = P_t + G_t - L_c + G_r - L_{\text{free}}(d) - L_{\text{feed}} - L_p + B_f \qquad (1)$$

where

P_t	transmitter power = 8.6 dBW (7.2 W)
G_t	AeroMACS antenna gain (8 dBi peak)
L_c	cable/line loss in AeroMACS transmission system = 1 dB
G_r	satellite antenna gain (6 dBi peak)
L_{free}	free-space path loss (dB)
L_{feed}	feed loss = 2.9 dB
L_p	polarization discrimination = 1 dB
B_{LEO}	receiver bandwidth at LEO satellite = 1.23 MHz
B_{AER}	transmitter bandwidth at AeroMACS ground station = 20 MHz
B_f	bandwidth factor = 10*log($B_{\text{LEO}}/B_{\text{AER}}$) = –12.1 dB
d	distance between AeroMACS transmitter and LEO satellite receiver (1414+ km)

The components of the model consist of antennas, stations, carriers, links, and interference paths. The details of building these components into the model are indicated below.

2.1 Antennas

2.1.1 Globalstar Antenna

From Reference 3, the Globalstar (LEO-D) satellite has a 100.9° field of view (FOV) which enables it to cover approximately 9% of the Earth's surface. Its receiving antenna has a maximum gain of 6 dBi at a nadir angle of 45°.

To model this antenna, the antenna submenu is selected and an antenna named 'Globalstar antenna' is entered (Fig. 1). The 'Edit' button is clicked, a circular beam is selected, and the 'Change' button is clicked. The following gain table (Fig. 2) is entered and the gain distribution is shown graphically in Figure 3.
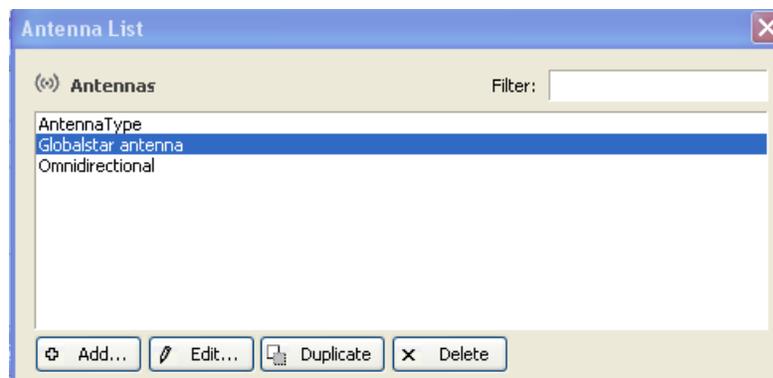
Figure 1.—Naming Globalstar antenna in Antenna submenu.
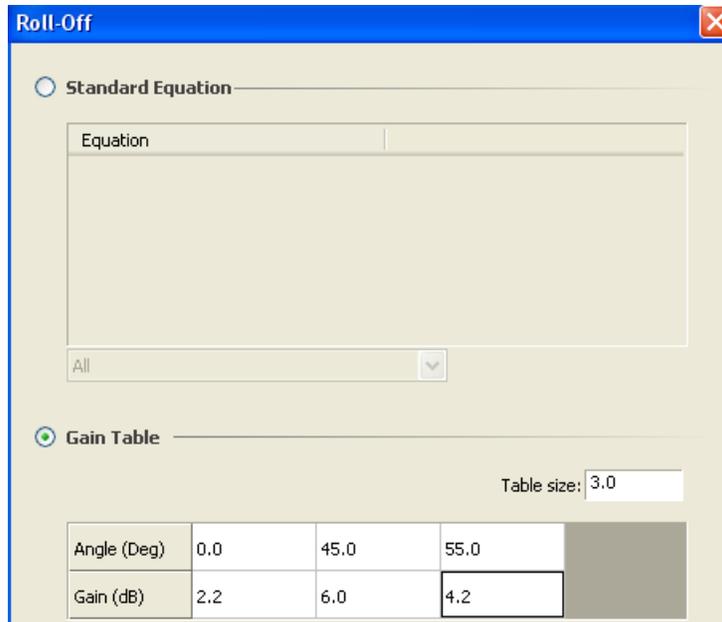
Figure 2.—Entering Globalstar receiving antenna gain distribution.
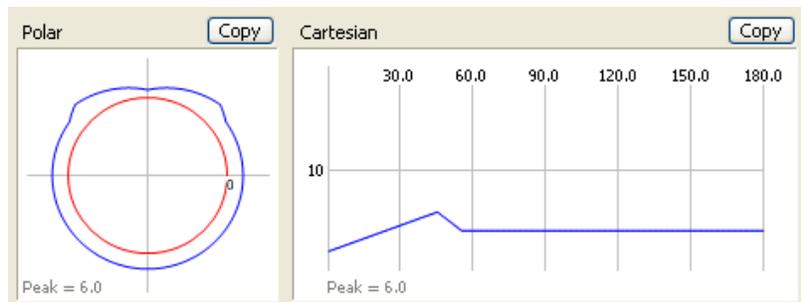
Figure 3.—Globalstar (LEO-D) satellite receiving antenna gain.

2.1.2 Omni-Directional Antenna (for AeroMACS Base Stations)

For this antenna, the gain pattern as a function of elevation angle is given in ITU-RF.1336-1 (Ref. 4) with maximum gain $G_0 = 8$ and

$$G(\theta) = \max\left[G_1(\theta), G_2(\theta)\right] \tag{2a}$$

$$G_1(\theta) = G_0 - 12\left(\frac{\theta}{\theta_3}\right)^2 \tag{2b}$$

$$G_2(\theta) = G_0 - 12 + 10\log\left[\left(\max\left\{\frac{|\theta|}{\theta_3}, 1\right\}\right)^{-1.5} + k\right] \tag{2c}$$

where
$G(\theta)$ gain relative to an isotropic antenna (dBi),
G_0 the maximum gain in or near the horizontal plane (dBi),
Θ absolute value of the elevation angle relative to the angle of maximum gain (degrees),

θ_3 the 3 dB beamwidth in the vertical plane (degrees), and

k parameter which accounts for increased side-lobe levels above what would be expected for an antenna with improved side-lobe performance.

The relationship between the gain (dBi) and the 3 dB beamwidth in the elevation plane (degrees) is:

$$\theta_3 = 107.6 \times 10^{-0.1\,G_0} \tag{2d}$$

In cases involving typical antennas operating in the 1 to 3 GHz range, the parameter k should be 0.7 (Ref. 4). The corresponding antenna gain as a function of elevation angle is shown in Figure 4. A shaped beam is selected in the Antenna Properties for the Omni-Directional Antenna. Equation (2a) is input into a Microsoft Excel (Microsoft Corporation) spreadsheet and the output is entered into the Elevation/Azimuth table shown in Figure 5.
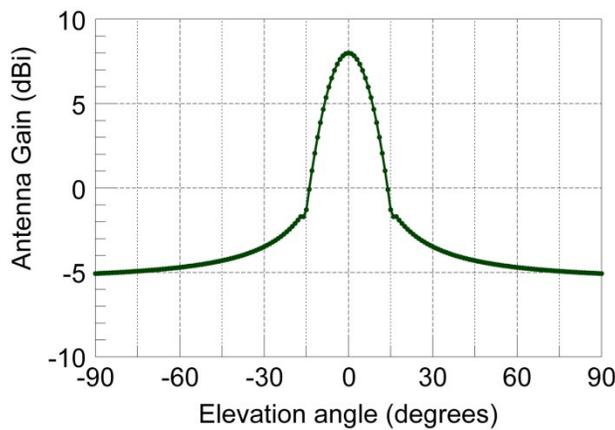
Figure 4.—Omni-directional AeroMACS base station antenna gain as a function of elevation angle.
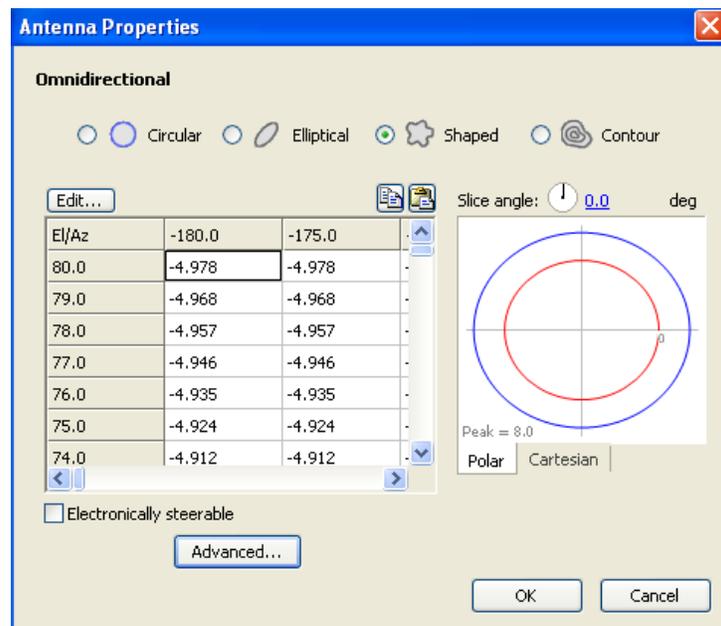
Figure 5.—Entering elevation gain pattern for base station omni-directional antenna.

2.2   Stations and Station Groups

Stations identify the locations of the transmitters and receivers. In the Station submenu (Fig. 6), a Globalstar (G*) satellite is added and through the Select Station Type submenu is defined to be a Terrestrial Fixed station. The position of a Globalstar satellite was then defined. The latitude and longitude were arbitrarily chosen and the altitude was defined to be that of the Globalstar orbits, 1414 km (Fig. 7). The Globalstar satellite was then linked to the previously defined Globalstar antenna (Fig. 8). A feeder loss of 2.9 dB was entered corresponding to the value in Table 3-2 of Reference 3. Because a Terrestrial Fixed Station was used to represent a satellite, the elevation needed to be set to –90°. One of the 497 airport base stations was also defined to be a Terrestrial Fixed Station and identified as Custom-2-2-1 (Fig. 9). Its latitude and longitude were entered and a height above terrain of 20 ft (6.096 m) was defined. Its antenna was linked to the omni-directional antenna previously defined (Fig. 10). This station is used as a template for the other 496 airport base station transmitters through the wizard in the Stations Groups submenu (Fig. 11). The latitudes and longitudes of the other base stations are entered through reading a comma-separated values (csv) file (Fig. 12). This results in a Station List of 1+497 = 498 stations (Fig. 13). In the Station Groups submenu, the airport base stations are linked together as 'Locations Service Area' (Fig. 14).

Figure 6.—Station types.

Figure 7.—Setting the position of a Globalstar satellite.

Figure 8.—Linking Globalstar satellite to Globalstar antenna.

Figure 9.—Defining the position of the first airport base station.
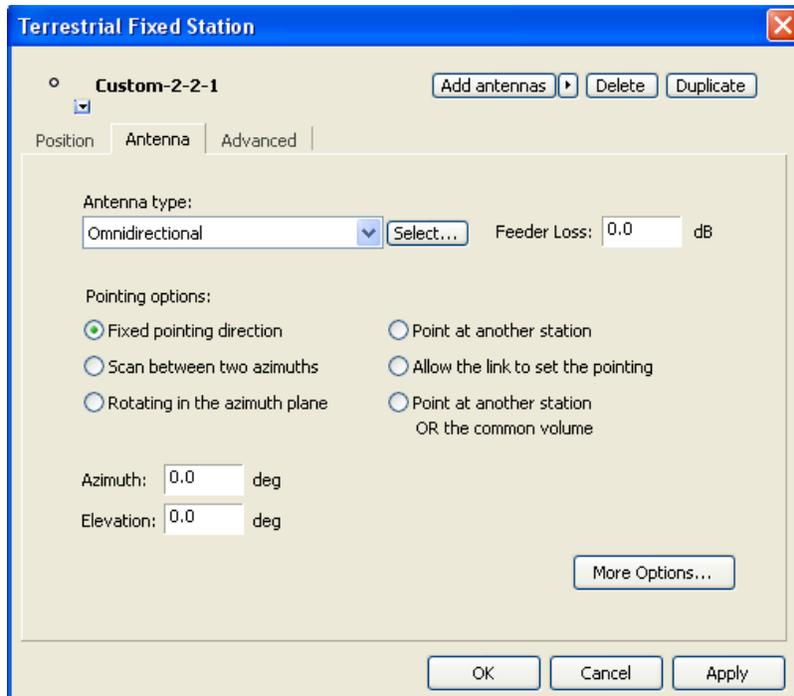
Figure 10.—Linking the first airport base station to the omni-directional antenna.
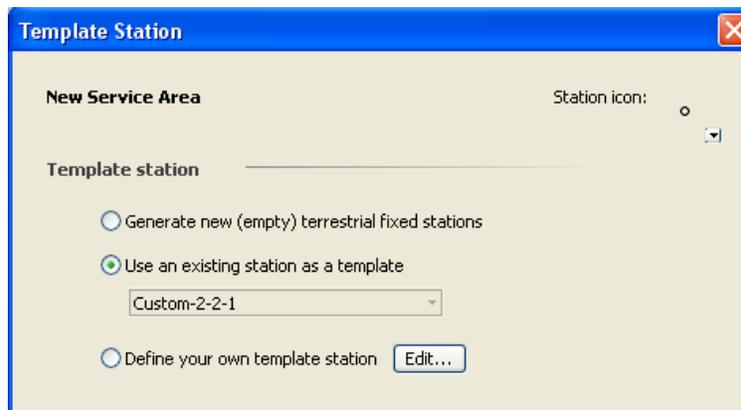
Figure 11.—Defining the first airport base station as a template.
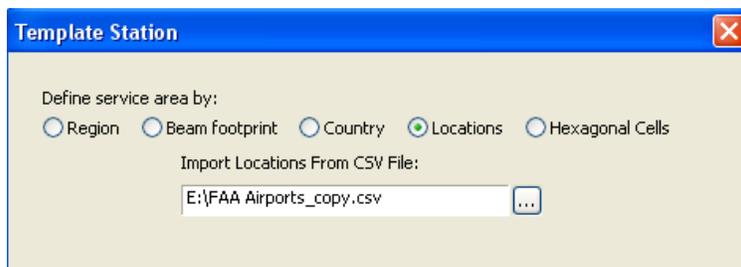
Figure 12.—The latitudes and longitudes of the other 496 airport base stations are entered.
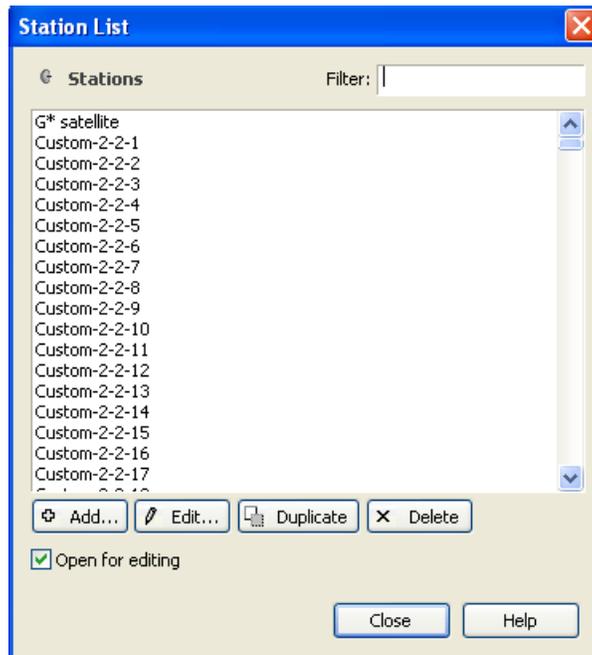
Figure 13.—List of stations include a Globalstar satellite and 497 airport base stations.
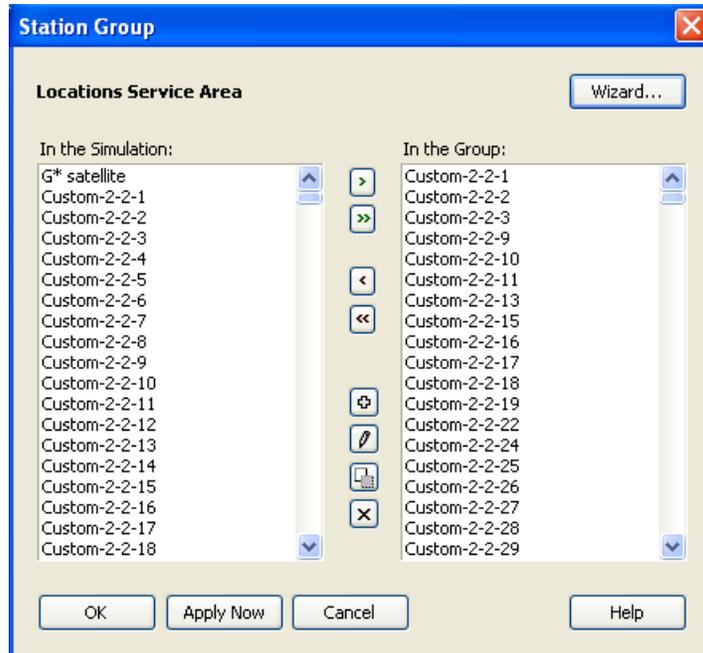
Figure 14.—The airport base stations are linked together as 'Locations Service Area'.

2.3   Carriers

The carrier submenu is used to designate bandwidths, polarization, and other characteristics of the signal spectrum. The AeroMACS carrier with 20 MHz bandwidth and Globalstar carrier with 1.23 MHz bandwidth are defined in Figures 15 and 16.
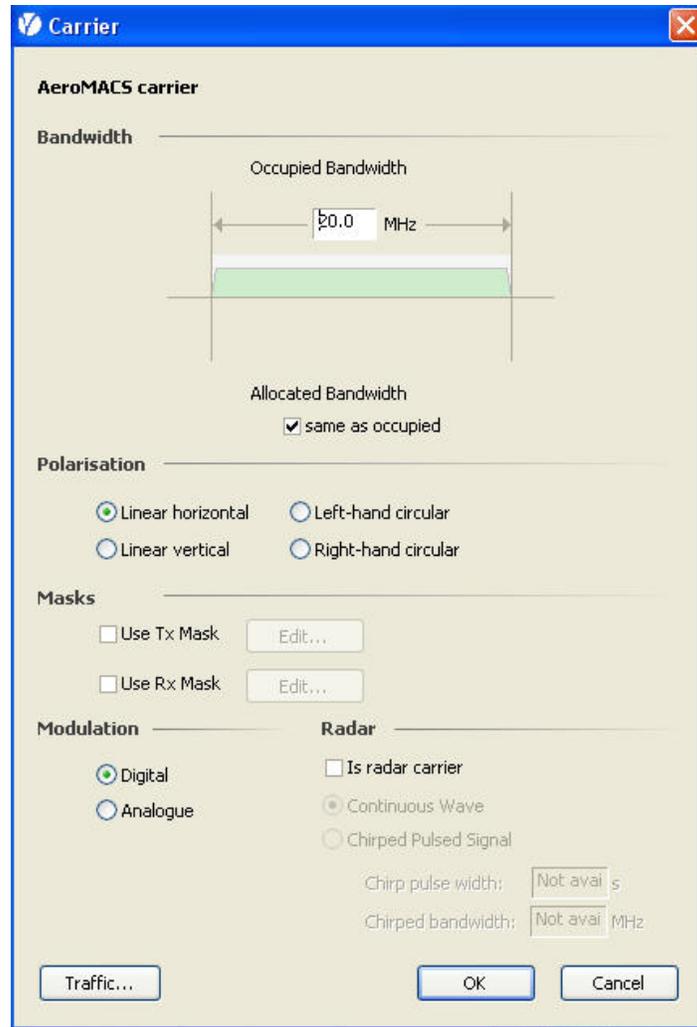
Figure 15.—Defining AeroMACS carrier.
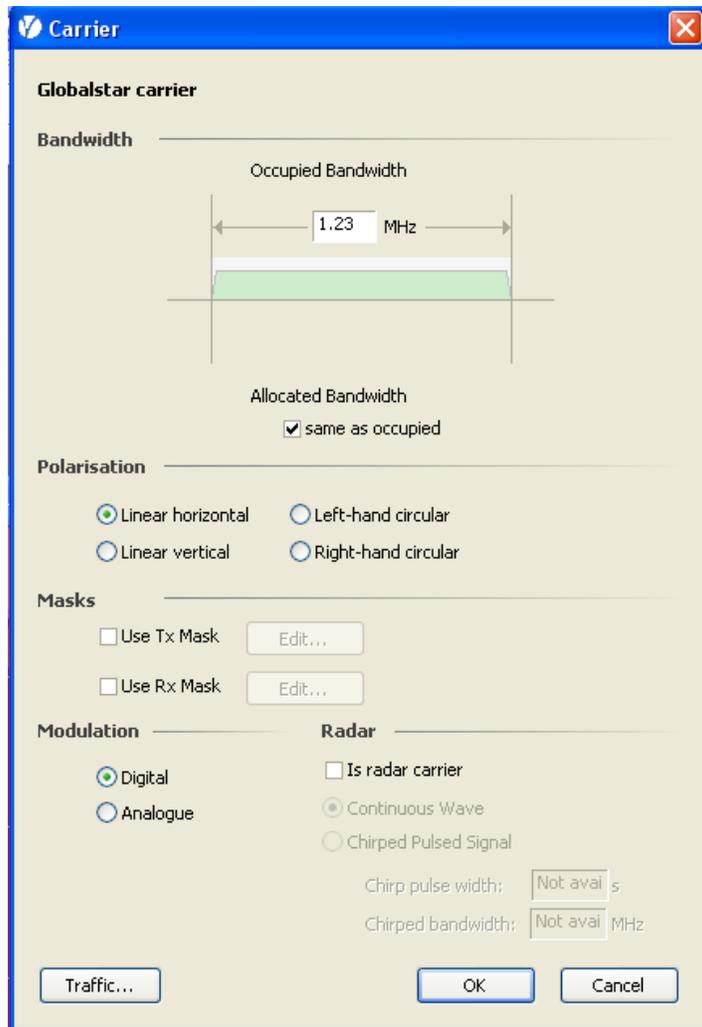
Figure 16.—Defining Globalstar carrier.

2.4   Links

Links are used to connect stations, define propagation parameters, and criteria for interference levels. A link defines a communications path. In this model, transmit links are defined from the airport transmitters and a receive link is defined at the Globalstar satellite. Transmitter links are defined for each of the 497 airport base stations in the 'Locations Service Area' (Fig. 17), each utilizing the previously defined AeroMACS carrier at 5.1 GHz with a transmitter power of 8.6 dBW (7.24 W). In Reference 3, it is assumed that there is 1 dB of line losses at the transmitters, so the transmit link power is set to 7.6 dBW (Fig. 18). The receiver link is defined at the Globalstar satellite (Fig. 19) and utilizes the Globalstar carrier at 5.1 GHz (Fig. 20).
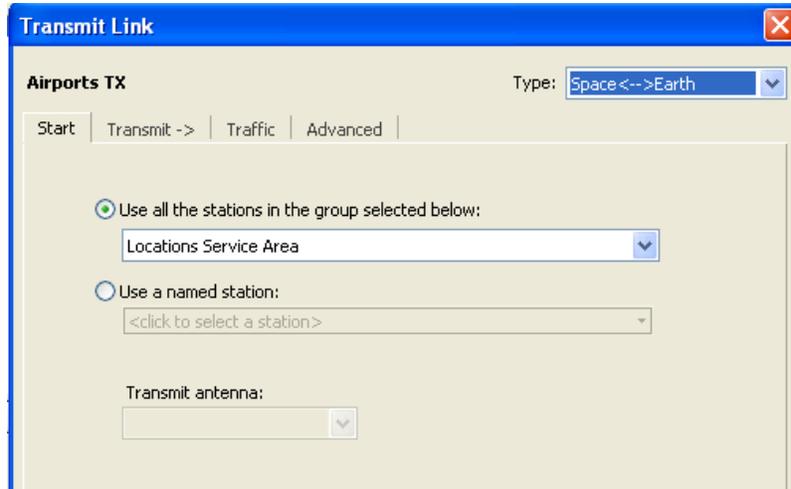
Figure 17.—Setting up transmit links at each of the airport base stations.
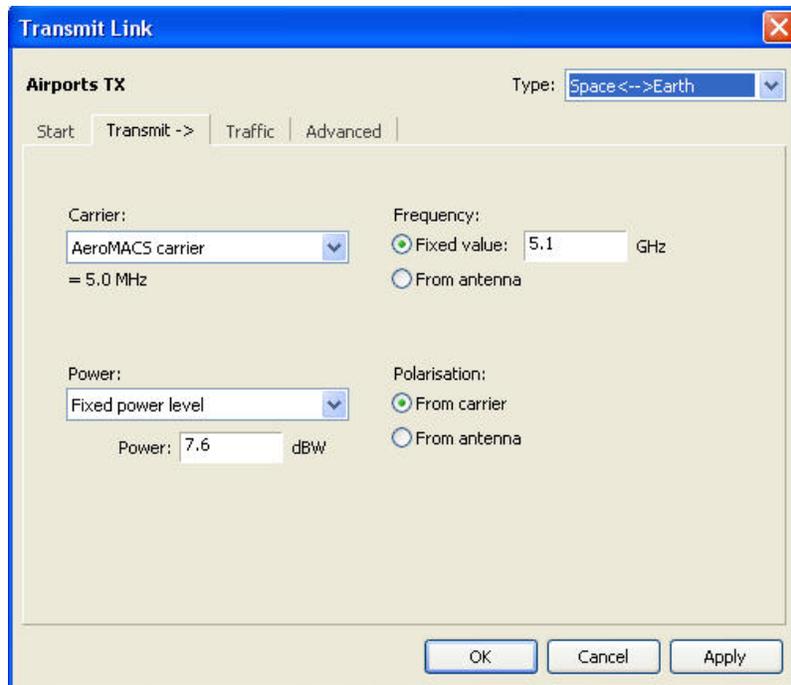
Figure 18.—The transmit links utilize the AeroMACS carrier at 5.1 GHz with a transmitter power of 8.6 dBW. (In Ref. 3, it is assumed that there is 1 dB of line losses at the transmitters, so the transmit link power is set to 7.6 dBW.)
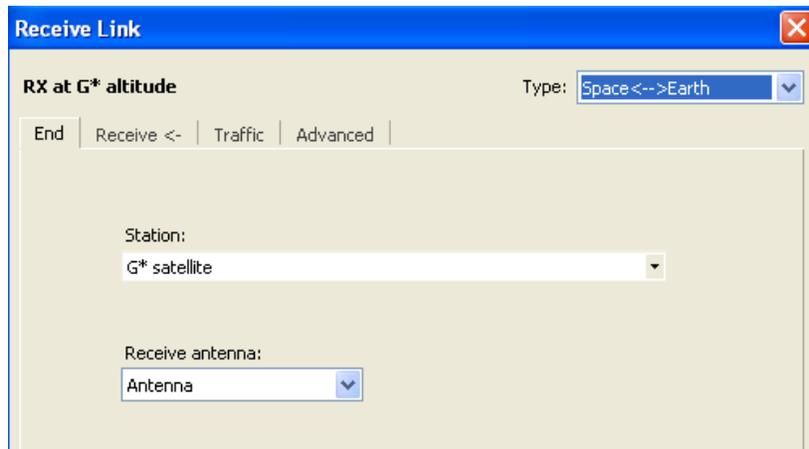
Figure 19.—Receive link defined at Globalstar satellite.
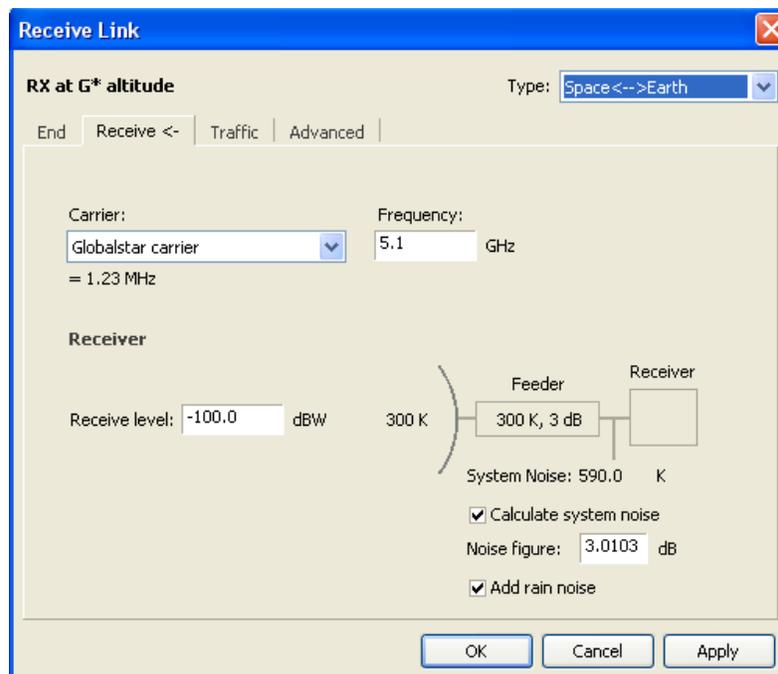
Figure 20.—Receive link utilizes Globalstar carrier.

All the links are defined as type 'Earth <-> Space'. Other types in Visualyse are Terrestrial Fixed, Terrestrial Mobile, Space <-> Space, and Broadcasting. With this type we can choose from a number of propagation models. The model ITU-R Rec. P.525, Basic Transmission Loss in Free Space (Ref. 5), is selected from the window below (Fig. 21).
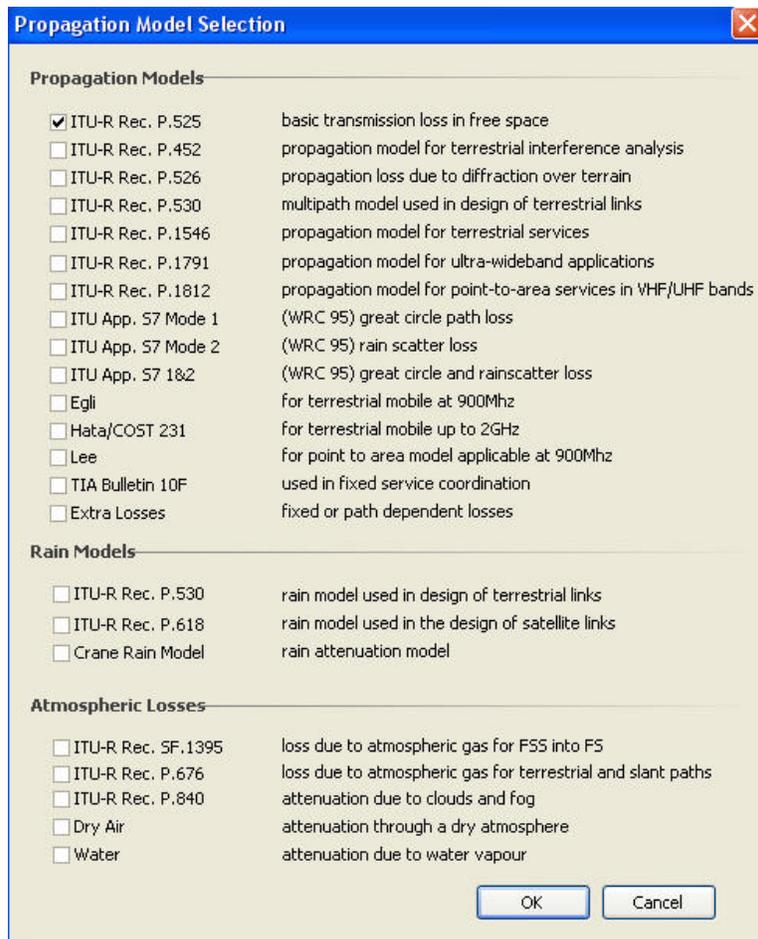
Figure 21.—Basic Transmission Loss in Free Space propagation
   model selected.

2.5 Interference Paths

An interference path consists of a wanted or 'victim' link and an unwanted or 'interfering' link or links (Fig. 22). In this case the interference path is designated as 'Airports into G*' to represent the Globalstar receive link as the victim link and the transmit links at each of the AeroMACS airport base stations as the interfering links (Fig. 23).

Figure 22.—Designating the Globalstar receive link as the 'wanted' link.
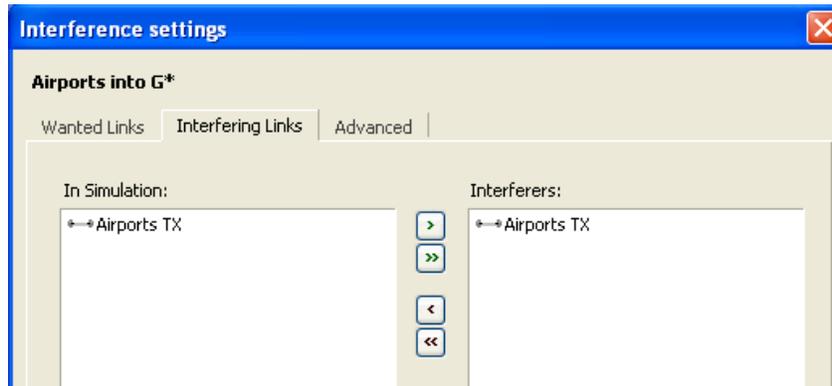
Figure 23.—Designating the transmit links at each of the AeroMACS airport base stations as the interfering links.

2.6 Output Menu

In order to plot the interference power over a map of the Western Hemisphere, the Create Area Analysis submenu is selected from the Output Menu and the following coordinates, station, link, and plot parameter are entered. The plot resolution is set to 175.74 km which provides 2° of longitude resolution (Fig. 24).

Figure 24.—Setting up the output map of interference power.

3.0   Results

The simulated interference power is shown in global view in Figure 25. The corresponding two-dimensional view is shown in Figure 26.
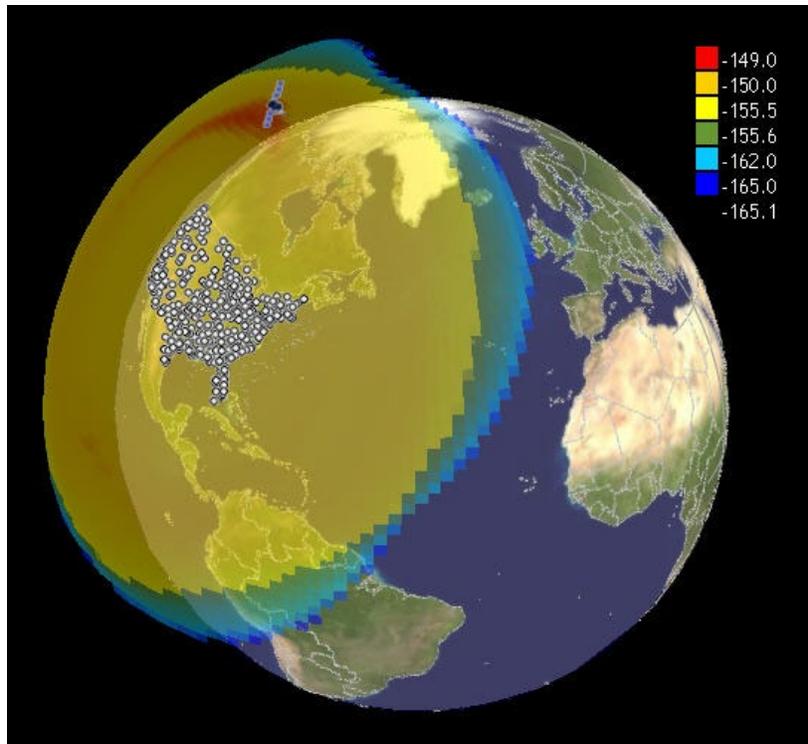
Figure 25.—Simulated interference power in global view.
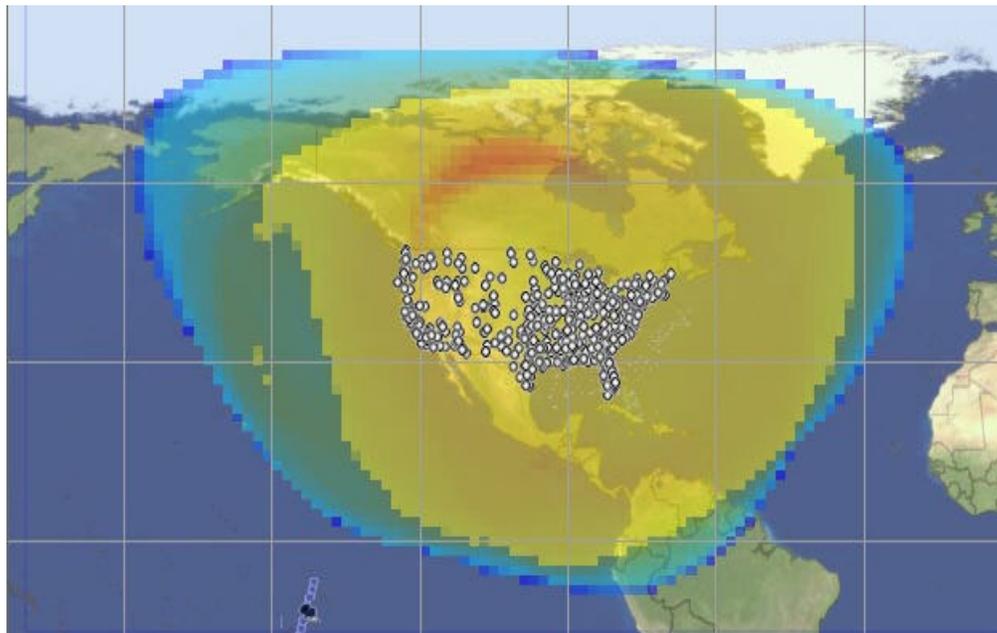
Figure 26.—Simulated interference power in two-dimensional view.

The agreement is excellent between the Visualyse simulated interference power distribution shown in Figure 26 and that calculated by Hoh, et al. in Reference 3. In the Visualyse model, the maximum interference power is –149.3 dBW at the location 64° N 105° W, which compares well with the value of –150.0 dBW in Reference 3 at the location 67° N 104° W. This maximum interference power over northern Canada is due to the maximum transmitting gain of the AeroMACS antennas in the horizontal direction.

4.0   Conclusions

The software program Visualyse Professional has been used to model a simplified architecture for the proposed Aeronautical Mobile Airport Communications System (AeroMACS). The model scenario consisted of a single omni-directional transmitting antenna at each of the 497 major contiguous United States airports. The AeroMACS transmitter power was chosen to be the same as a previous study in order to verify the model. Details of the model building were described and the results agreed closely to that of the previous study in which the interference power over almost all of North America exceeds the desired threshold. This agreement provides confidence that the model is accurate and serves as a starting point for developing and investigating more sophisticated and realistic AeroMACS scenarios.

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3. Y.-S. Hoh, I.L. Gheorghisor, and F. Box, "Feasibility Analysis of 5091-5150 MHz Band Sharing by ANLE and MSS Feeder Links," MITRE-CAASD Report MP 05W0000083, 2005.
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5. Recommendation ITU-R P.525-2, "Calculation of Free-Space Attenuation," 1978–1994.

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13. SUPPLEMENTARY NOTES

14. ABSTRACT
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