# POWER DENSITY CALCULATIONS FOR TRANSMITTED SIGNALS FROM 2.4-METER KU-BAND SATELLITE EARTH STATION

## I. SIGNAL TYPES AND BANDWIDTHS

At any given time during the operation of the Ku-band satellite earth station, one of the following signal types will be uplinked to a selected satellite within the domestic arc.

| Signal Type | Occupied Signal Bandwidth |
|---|---|
| 1. Digital QPSK (low-rate SCPC compressed digital video) | 4.00 MHz |
| 2. Digital QPSK (low-rate SCPC compressed digital video) | 6.00 MHz |

## II. SIGNAL COMBINATIONS AND PER-CARRIER POWER LEVELS

Current operational plans for the Ku-band satellite earth station include the following uplinked signal(s):

- One or more low-rate SCPC compressed digital video signals (Type 1 or 2), with per-carrier RF power density levels (into the antenna) that will not exceed -14.0 dBW/4 kHz.

## III. INPUT POWER LEVELS AND POWER DENSITIES (TO ANTENNA)

For any of the specified transmitted signal types, the RF power density into the antenna is given by:

Power Density (dBW/4 kHz) = P (dBW) + 36.0 dB-Hz - 10 log B + PF,

where P = per-carrier input power (to the antenna)

36.0 dB-Hz is a factor to convert power density from a 1 Hz bandwidth to a 4 kHz bandwidth

B is the bandwidth occupied by the signal

PF = signal peaking factor (dependent on the signal type)

The per-carrier input power (to the antenna) is determined by reducing the per-carrier output power from the HPA by the transmitting system losses, or

$$P\ (dBW) = P_t\ (dBW) + L_t\ (dB)$$

where $P_t$ = per-carrier output power (from the HPA)

and $L_t$ = transmitting system losses (a fractional numeric, with a negative dB value)

For routine licensing of Ku-band narrowband digital transmissions from antennas less than 5 meters in diameter, it is understood that the per-carrier power density into the antenna should be no greater than -14.0 dBW/4 kHz. No specific additional constraints/limitations related to transmitted power levels (or power densities) of narrowband digital signals at Ku-band are known to exist.

As shown below, all signals to be transmitted from the Ku-band satellite earth station will be operated in strict compliance with all known applicable limitations on input power levels and input power densities for Ku-band signals. The maximum power levels are established for both signal types listed in Section I, and the input power densities are calculated for each. Maximum EIRP and EIRP density levels, both on-axis and toward the horizon, are also calculated for the specified signal types. The specified SCPC compressed digital video signals will be operated such that the requirements for narrowband digital transmissions will be satisfied.

## A. LOW-RATE SCPC COMPRESSED DIGITAL VIDEO SIGNALS (Type 1)

### 1. Input Power Level (to antenna)

For the Ku-band satellite earth station, the maximum operating power level (at the output of the HPA) for a low-rate SCPC compressed digital video signal (Type 1) will never exceed 60 Watts (17.8 dBW). Using a minimum value of 3.0 dB for the aggregate transmitting system losses, the corresponding maximum power level into the antenna will therefore be:

$$P\ (dBW) = P_t\ (dBW) + L_t\ (dB)$$

$$= 17.8\ dBW - 3.0\ dB$$

$$= 14.8\ dBW$$

A per-carrier operating input power level of 14.8 dBW will be substantially above what will be required for good performance margins to a network of 1.2-m to 1.8-m receiving antennas. Such a high power level will normally only be used during occasional periods of uplink degradation due to rainfall.

### 2. Input Power Density (to antenna)

Assuming a maximum antenna input power level of 14.8 dBW, the worst-case input power density for a Type 1 low-rate SCPC compressed digital video signal can be determined. This signal is in the MPEG2/DVB SCPC format, with an information rate of 4.15 Mbps. Use of 3/4 convolutional and Reed-Solomon FEC encoding results in a transmitted data rate of approximately 6.0 Mbps. The modulation technique is QPSK and the transmitted symbol rate is approximately 3.0 Msps. The occupied signal bandwidth is approximately 4.00 Mhz, but (for conservatism) an even lower bandwidth equal to the symbol rate of 3.0 MHz (64.8 dB-Hz) will be used to calculate the input power density to the antenna. For this bandwidth, a peaking factor of 0.0 dB can be safely assumed, and the calculation is as follows:

$$\text{Input Power Density (dBW/4 kHz)} = P\ (dBW) + 36.0\ dB\text{-}Hz - 10 \log B + PF$$

$$= 14.8\ dBW + 36.0\ dB\text{-}Hz - 64.8\ dB\text{-}Hz + 0.0\ dB$$

$$= -14.0\ dBW/4\ kHz$$

***Under no circumstances will the input power density (to the antenna) of a Type 1 low-rate SCPC compressed digital video signal be permitted to exceed -14.0 dBW/4 kHz.***

## B. LOW-RATE SCPC COMPRESSED DIGITAL VIDEO SIGNALS (Type 2)

### 1. Input Power Level (to antenna)

For the Ku-band satellite earth station, the maximum operating power level (at the output of the HPA) for a low-rate SCPC compressed digital video signal (Type 2) will never exceed 90 Watts (19.5 dBW). Using a minimum value of 3.0 dB for the aggregate transmitting system losses, the corresponding maximum power level into the antenna will therefore be:

$$P\ (dBW) = P_t\ (dBW) + L_t\ (dB)$$

$$= 19.5\ dBW - 3.0\ dB$$

$$= 16.5\ dBW$$

A per-carrier operating input power level of 16.5 dBW will be substantially above what will be required for good performance margins to a network of 1.2-m to 1.8-m receiving antennas. Such a high power level will normally only be used during occasional periods of uplink degradation due to rainfall.

### 2. Input Power Density (to antenna)

Assuming a maximum antenna input power level of 16.5 dBW, the worst-case input power density for a Type 2 low-rate SCPC compressed digital video signal can be determined. This signal is in the MPEG2/DVB SCPC format, with an information rate of 6.22 Mbps. Use of 3/4 convolutional and Reed-Solomon FEC encoding results in a transmitted data rate of approximately 9.0 Mbps. The modulation technique is QPSK and the transmitted symbol rate is approximately 4.5 Msps. The occupied signal bandwidth is approximately 6.00 Mhz, but (for conservatism) an even lower bandwidth equal to the symbol rate of 4.5 MHz (66.5 dB-Hz) will be used to calculate the input power density to the antenna. For this bandwidth, a peaking factor of 0.0 dB can be safely assumed, and the calculation is as follows:

$$\text{Input Power Density (dBW/4 kHz)} = P\ (dBW) + 36.0\ dB\text{-}Hz - 10 \log B + PF$$

$$= 16.5\ dBW + 36.0\ dB\text{-}Hz - 66.5\ dB\text{-}Hz + 0.0\ dB$$

$$= -14.0\ dBW/4\ kHz$$

***Under no circumstances will the input power density (to the antenna) of a Type 2 low-rate SCPC compressed digital video signal be permitted to exceed -14.0 dBW/4 kHz.***

## IV. TRANSMITTED EIRPs AND EIRP DENSITIES (FROM ANTENNA)

For the Ku-band satellite earth station, the maximum (on-axis) value of per-carrier EIRP is calculated as follows:

$$\text{EIRP (dBW)} = P_t \text{ (dBW)} + L_t \text{ (dB)} + G_t \text{ (dBi)} ,$$

where $P_t$ = maximum value of per-carrier power (from the HPA)

$L_t$ = minimum value of transmitting system losses = - 3.0 dB

$G_t$ = maximum value of transmit antenna gain = 48.8 dBi

For a given transmitted signal, the maximum (on-axis) RF power density (at the output of the antenna) is given by:

$$\text{EIRP Density (dBW/4 kHz)} = \text{EIRP (dBW)} + 36.0 \text{ dB-Hz} - 10 \log B + PF,$$

where EIRP = maximum (on-axis) value of per-carrier output EIRP

36.0 dB-Hz is a factor to convert power density from a 1 Hz bandwidth to a 4 kHz bandwidth

B is the bandwidth occupied by the signal

PF = signal peaking factor (dependent on the signal type)

Equivalently, maximum (on-axis) EIRP density values can be determined by simply increasing the maximum values of per-carrier input power density (determined previously for each signal type) by the on-axis antenna gain.

At any off-axis angle, the EIRP and EIRP density values will be reduced by an amount equal to the antenna gain reduction. For any given transmitted signal type from the Ku-band satellite earth station being considered, the maximum EIRP density toward the horizon will occur when the elevation angle is at its minimum value of 28.5 degrees. At an off-axis angle of 28.5 degrees, the antenna gain will be no greater than the allowable sidelobe envelope. At this angle, the off-axis gain will therefore be no greater than:

$$29 - 25\log (28.5 \text{ deg}) = -7.4 \text{ dBi}$$

The gain reduction at an off-axis angle of 28.5 degrees will be equal to the difference in on-axis and off-axis gain values, and will be at least:

55.0 dBi - (-7.4 dBi) = 62.4 dB

## A. LOW-RATE SCPC COMPRESSED DIGITAL VIDEO SIGNALS (Type 1)

### 1. Maximum EIRP (on-axis)

Assuming that per-carrier input power level (to the antenna) is increased up to its maximum allowable value of 14.8 dBW, the maximum EIRP for the specified low-rate SCPC compressed digital video signal can be determined as follows:

EIRP (dBW) = $P_t$ (dBW) + $L_t$ (dB) + $G_t$ (dBi) ,

= 17.8 dBW - 3.0 dB + 48.8 dBi

= 63.6 dBW

### 2. Maximum EIRP Density (on-axis)

EIRP Density (dBW/4 kHz) = EIRP (dBW) + 36.0 dB-Hz - 10 log B + PF

= 63.6 dBW + 36.0 dB-Hz - 64.8 dB-Hz + 0.0 dB

= 34.8 dBW/4 kHz

### 3. Maximum EIRP Density (toward horizon)

EIRP Density (at 28.5 degrees) = EIRP Density (on-axis) - 62.4 dB

= 34.8 dBW/4 kHz - 62.4 dB

= -27.6 dBW/4 kHz

**B. LOW-RATE SCPC COMPRESSED DIGITAL VIDEO SIGNALS (Type 2)**

**1. Maximum EIRP (on-axis)**

Assuming that per-carrier input power level (to the antenna) is increased up to its maximum allowable value of 16.5 dBW, the maximum EIRP for the specified low-rate SCPC compressed digital video signal can be determined as follows:

EIRP (dBW) = $P_t$ (dBW) + $L_t$ (dB) + $G_t$ (dBi) ,

= 19.5 dBW - 3.0 dB + 48.8 dBi

= 65.3 dBW

**2. Maximum EIRP Density (on-axis)**

EIRP Density (dBW/4 kHz) = EIRP (dBW) + 36.0 dB-Hz - 10 log B + PF

= 65.3 dBW + 36.0 dB-Hz - 66.5 dB-Hz + 0.0 dB

= 34.8 dBW/4 kHz

**3. Maximum EIRP Density (toward horizon)**

EIRP Density (at 28.5 degrees) = EIRP Density (on-axis) - 62.4 dB

= 34.8 dBW/4 kHz - 62.4 dB

= -27.6 dBW/4 kHz

## V. SUMMARY OF CALCULATION RESULTS

| Signal Type | Minimum Signal Bandwidth (MHz) | Maximum Input Power to Antenna (dBW) | Maximum Input Power Density to Antenna (dBW/4 kHz) | Maximum On-Axis EIRP (dBW) | Maximum On-Axis EIRP Density (dBW/4 kHz) | Maximum EIRP Density toward Horizon (dBW/4kHz) |
|---|---|---|---|---|---|---|
| Digital QPSK (low-rate SCPC compressed digital video) | 3.0* | 14.8 | -14.0 | 63.6 | 34.8 | -27.6 |
| Digital QPSK (low-rate SCPC compressed digital video) | 4.5* | 16.5 | -14.0 | 65.3 | 34.8 | -27.6 |

***Symbol rate bandwidth (very conservative assumption).***

## VI. CONCLUSIONS

The analyses presented herein, and summarized in the preceding table, show that the maximum power levels and maximum power density values for the given signal types are all within the values that are considered applicable for routine licensing of Ku-band transmit/receive earth stations.