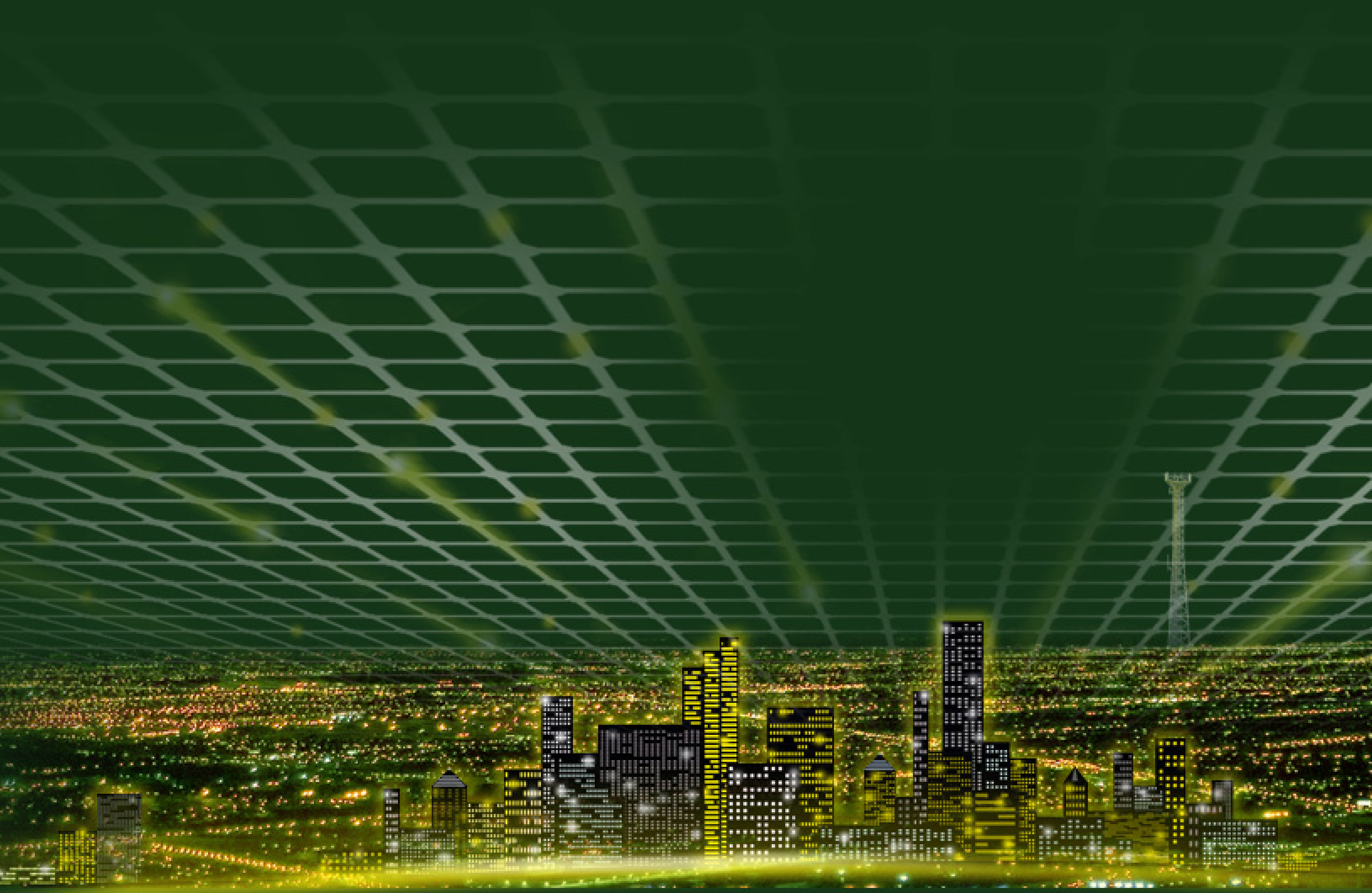
Sensus FlexNet

MPE Calculations for FlexNet Endpoint-Equipped Electric and Gas Meters



1 Electric Meters

1.1 Introduction

The following calculations are given to show that a Sensus Flexnet equipped electric meter complies to FCC OET-65 limits for Maximum Permissible Exposure (MPE) and provides a minimum separation distance based on the calculations and guidelines of that document.

Robert J Davis,

Principal RF Engineer

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1.2 MPE Calculations for General Population/Uncontrolled Exposure

Given:

- The transmitter is considered a mobile apparatus (as opposed to portable).
- A lowest frequency of operation being 880 MHz.
- The power into the antenna is measured to be 30 dBm.
- The antenna gain is 0 dBi
- The limit for Power Density (S) is selected for compliance for General Population and Uncontrolled Exposure which relates to:
  - o S = f / 1500 mW/cm^2
  - o For 880 MHz S = 880 / 1500 = 0.586 = 0.6 mW/cm^2 (Which would be the worst case over the transmitter operating range of 880 to 925 MHz even though it's a smaller number (see R equation below)).
  - o The value of S directly relates to the MPE (Maximum Permissible Exposure) limit set forth by FCC OET-65.

Using the FCC supplied equation for Power Density (S):

$$S = \frac{P*G}{4*\pi*R^2}$$

(Equation 1) [1]

Where:

P = 30 dBm = (10$^{(30/10)}$ * 001) = 1.00 Watts = 1000 mW

G = 0 dBi = 10$^{(0/10)}$ = 1.0 (Numeric)

R = Distance to Center Of Radiation of the Antenna in cm.

S = 0.6 mW/cm^2

R = SQRT((P*G)/(4*π*S))

R = SQRT((1260*1)/(4*3.14*0.6)) = 12.93 cm

Solving for R would give a separation distance of 13 centimeters to meet the MPE limit of 0.6 mW/cm^2 if the transmitter was in *continuous* operation, which is not the case. The 13 cm separation is well within the 20 cm limit that the FCC mandates for mobile operation as stated on the grant of equipment authorization for the transmitter.

FCC OET-65 allows for time averaging power density over a period of 30 minutes for installations that apply to general population and uncontrolled exposure. Using the equations provided in OET-65 we may determine the average power density (S) that would be encountered by the general population over a 30 minute time interval and relate that to a minimum distance that should be maintained from the transmitter antenna.

(From FCC OET-65) The sum of the product of the exposure levels and the allowed times for exposure must equal the product of the appropriate time averaging interval:

1. FCC OET Bulletin 65, Edition 97-01. August 97. Equation 3, Page 19

$$\sum S_{exp} t_{exp} = S_{limit} t_{avg}$$

(Equation 2)[2]

Where:

- S_{exp} = power density level of exposure (mW/cm^2)
- S_{limit} = appropriate power density MPE limit (mW/cm^2)
- t_{exp} = allowable time of exposure for (S_{exp})
- t_{avg} = appropriate MPE averaging time.

For our application the MPE limit is 0.6 mW/cm^2 and the time period allowed for time averaging is 30 minutes (from OET-65 for general population and uncontrolled exposure). Thus the right hand side of the equation becomes (in seconds):

$S_{limit} t_{avg}$ = 0.6 mW/cm^2 * 30 Minutes * 60 Seconds = 1080 mW-sec/cm^2

For an electricity meter, there are several transmission types that may be generated by the endpoint. The transmission type that has the potential of generating the highest number of RF emissions over the averaging intervals the FCC uses for MPE calculations is the “normal mode”.

The endpoint cannot continuously generate transmissions as the energy used to generate those transmissions is stored in a large capacitor. The capacitor can store enough energy to allow the endpoint to transmit 3 RF messages before it has to be recharged. The time it takes to recharge the capacitor is 6 seconds. (Note: Circuitry on the endpoint ensures that the capacitor reaches full charge before the transmitter is allowed to transmit again.)

Under normal operation of the meter, the transmitter should never obtain a duty cycle of 3 transmitted messages every 6 seconds. The worst case scenario for transmitter operation will occur when the endpoint relays a message it receives from another meter (this is referred to as message pass, or “buddy mode”).

When the endpoint relays (or “buddies”) another transmission it first sends a normal mode message containing the same information that was transmitted by the meter it is repeating. Immediately after this initial message is transmitted another normal mode message is transmitted with certain housekeeping and status information pertaining to the meter that was repeated (i.e., received signal strength of the repeated meter, etc.).

The rate at which any given endpoint can process the received message from the meter it is repeating, and subsequently transmit the relayed messages is once per 6 seconds due to power supply and signal processing time restraints in the endpoint itself. Thus, a worst case transmission rate of 2 normal mode messages (107 milliseconds each in duration), every 6 seconds is proposed.

2. FCC OET Bulletin 65, Edition 97-01, August 97. Equation 2, Page 11

RF Message Length Transmitting Normal Mode:	107 milliseconds
Time To Charge Capacitor And Be Ready For Next Transmission:	6 Seconds
Thus, 2 Messages may be transmitted in [6 + (.107 * 2)] =	6.214 Seconds
Time Averaging Window For Uncontrolled Population Per OET-65:	30 Minutes
Number Of Messages That May Be Transmitted In 30 Minutes:	[1800 / 6.214 = 289]
Total On Air Time Over 30 Minutes:	61.85 Seconds
(Transmissions) Seconds Per Message]	[289 * 0.107 * 2]

NOTE: The endpoint probably will not generate the number of messages in the MPE averaging interval (as shown above) due to actual system and hardware constraints, but the calculations assume that it does for the sake of argument. This number of messages would only occur if the meter were to continually transmit buddy messages and replies over the whole 30 minute interval, which is highly unlikely.

Solving Equation 2 for S_{exp} using a total on air time of 61.85 seconds yields a value of:

$S_{exp} = (S_{limit}\ t_{avg})/\ t_{exp}$ = (1080 mW-sec / cm^2) / (61.85 seconds) = 17.4 mW/cm^2

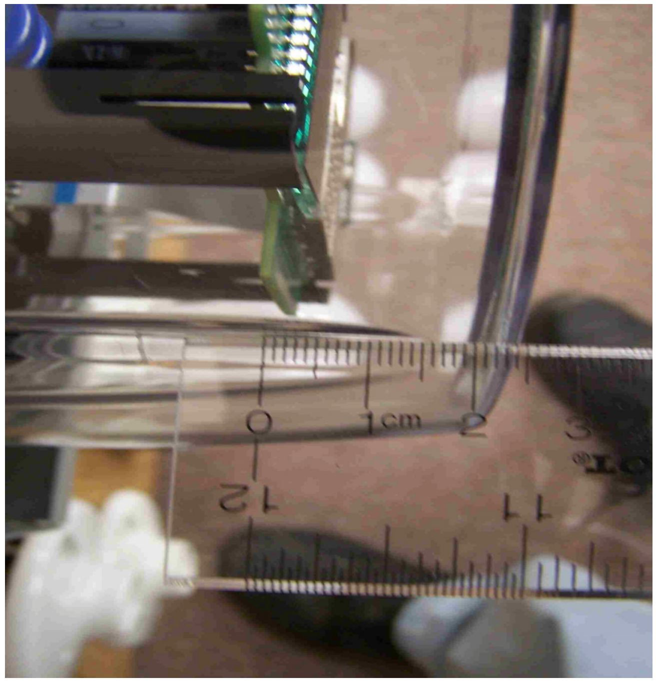
To determine what distance would be required to generate this exposure limit we need to refer to Equation 1 and solve for the distance R:

R = SQRT((P*G)/(4*π*S))

R = SQRT((1000*1)/(4*3.14**17.4*)) = 2.14 cm

R = 2.14 cm / 2.54 cm/inch = 0.84 inches

The antenna on the endpoint lies “under the glass” by a separation of 2.2centimeters (see picture below):



1.3 Summary for Uncontrolled Exposure

With the endpoint transmitting as many messages as is theoretically possible due to system design between messages, the MPE limits for general population / uncontrolled exposure would be met as the meter glass provides enough separation between the antenna and the general population.

1.4 MPE Calculations For Occupational/Controlled Exposure

Given:

- The transmitter is considered a mobile apparatus (as opposed to portable).
- A lowest frequency of operation being 880 MHz.
- The power into the antenna is measured to be 30 dBm.
- The antenna gain is 0 dBi
- The limit for Power Density (S) is selected for compliance for Occupational / Controlled Exposure which relates to:
  - $S = f / 300\ mW/cm^2$
  - For 880 MHz $S = 880 / 300 = 2.93333 = 2.93\ mW/cm^2$ (Which would be the worst case over the transmitter operating range of 880 to 925 MHz even though it's a lower number (see R equation below).)
  - The value of S directly relates to the MPE (Maximum Permissible Exposure) limit set forth by FCC OET-65.

Using the FCC supplied equation for Power Density (S):

$$S = \frac{P*G}{4*\pi*R^2}$$

(Equation 1)[3]

Where:

$P = 30\ dBm = (10^{(30/10)} * 001) = 1.00$ Watts = 1000 mW

$G = 0\ dBi = 10^{(0/10)} = 1.0$ (Numeric)

R = Distance To Center Of Radiation Of The Antenna In cm.

$S = 2.93\ mW/cm^2$

R = SQRT((P*G)/(4*π*S))

R = SQRT((1000*1)/(4*3.14*2.93)) = 5.21 cm

Solving For R would give a separation distance of 5.2 centimeters to meet the MPE limit of 2.93 mW/cm^2 if the transmitter was in *continuous* operation which is not the case. The 5.2 cm separation is well within the 20 cm limit that the FCC mandates for mobile operation as stated on the grant of equipment authorization for the transmitter.

FCC OET-65 allows for time averaging power density over a period of 6 minutes for installations that apply to Occupational and Controlled Exposure. Using the equations provided in OET-65 (page 11) we may determine the average power density (S) that would be encountered over a 6 minute time interval and relate that to a minimum distance that should be maintained from the transmitter antenna.

3. FCC OET Bulletin 65, Edition 97-01. August 97. Equation 3, Page 19

(From FCC OET-65) The sum of the product of the exposure levels and the allowed times for exposure must equal the product of the appropriate time averaging interval:

$$\sum S_{exp}\, t_{exp} = S_{limit}\, t_{avg}$$

(Equation 2)[4]

Where:

S_{exp} = power density level of exposure (mW/cm^2)

S_{limit} = appropriate power density MPE limit (mW/cm^2)

t_{exp} = allowable time of exposure for (S_{exp})

t_{avg} = appropriate MPE averaging time.

For our application the MPE limit is 2.93 mW/cm^2 and the time period allowed for time averaging is 6 minutes (from OET-65 for occupational and controlled exposure). Thus the right hand side of the equation becomes (in seconds):

$S_{limit}\, t_{avg}$ = 2.93 mW/cm^2 *6 Minutes*60 Seconds = 1054.8 mW-sec / cm^2

For an electricity meter, there are several transmission types that may be generated by the endpoint. The transmission type that has the potential of generating the highest number of RF emissions over the averaging intervals the FCC uses for MPE calculations is the “normal mode”.

The endpoint cannot continuously generate transmissions as the energy used to generate those transmissions is stored in a large capacitor. The capacitor can store enough energy to allow the endpoint to transmit 3 RF messages before it has to be recharged. The time it takes to recharge the capacitor is 6 seconds. (Note: Circuitry on the endpoint ensures that the capacitor reaches full charge before the transmitter is allowed to transmit again.)

Under normal operation of the meter, the transmitter should never obtain a duty cycle of 3 transmitted messages every 6 seconds. The worst case scenario for transmitter operation will occur when the endpoint relays a message it receives from another meter (this is referred to as message pass, or “buddy mode”).

When the endpoint relays (or “buddies”) another transmission it first sends a normal mode message containing the same information that was transmitted by the meter it is repeating. Immediately after this initial message is transmitted another normal mode message is transmitted with certain housekeeping and status information pertaining to the meter that was repeated (i.e. received signal strength of the repeated meter, etc.).

The rate at which any given endpoint can process the received message from the meter it is repeating, and subsequently transmit the relayed messages is once per 6 seconds due to power supply and signal processing time restraints in the endpoint itself. Thus a worse case transmission rate of 2 normal mode messages (107 milliseconds each in duration), every 6 seconds is proposed.

4. FCC OET Bulletin 65, Edition 97-01, August 97. Equation 2, Page 11

RF Message Length Transmitting Normal Mode:	107 milliseconds
Time To Charge Capacitor And Be Ready For Next Transmission:	6 Seconds
Thus, 2 Messages may be transmitted in [6 + (.107 * 2)] =	6.214 Seconds
Time Averaging Window For Uncontrolled Population Per OET-65:	6 Minutes
Number Of Messages That May Be Transmitted In 6 Minutes:	58: [360 / 6.214 = 57.9]
Total On Air Time Over 30 Minutes:	12.4 Seconds
(Transmissions) Seconds Per Message:	58 * 0.107 * 2

NOTE: The endpoint probably will not generate the number of messages in the MPE averaging interval (as shown above) due to actual system and hardware constraints, but the calculations assume that it does for the sake of argument. This number of messages would only occur if the meter were to continually transmit buddy messages and replies over the whole 30 minute interval, which is highly unlikely.

Solving Equation 2 for S_{exp} using a total on air time of 61.85 seconds and the S limit for occupational/ controlled exposure yields a value of:

$S_{exp} = (S_{limit}\ t_{avg})/\ t_{exp}$ = (1054.8 mW-sec / cm^2) / (12.4 seconds) = 85.1 mW/cm^2

To determine what distance would be required to generate this exposure limit we need to refer to Equation 1 and solve for the distance R:

R = SQRT((P*G)/(4*π*S))

R = SQRT((1000*1)/(4*3.14**85.1*)) = .933 cm

R = .933 cm / 2.54 cm/inch = .367 inches

1.5 Summary for Controlled Exposure

With the endpoint transmitting as many messages as is theoretically possible due to it’s hardware and system design (with no processing time as is needed) between messages, the MPE limits for Occupational / Controlled Exposure would be met as the meter glass provides enough separation between the antenna and the general population. (See earlier picture).

2 Gas Meters

2.1 Introduction

The following calculations are given to show that a Sensus Flexnet Gas meter complies to FCC OET-65 limits for Maximum Permissible Exposure (MPE) and provides a minimum separation distance based on the calculations and guidelines of that document.

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2.2 MPE Calculations for General Population/Uncontrolled Exposure

Given:

- The transmitter is considered a mobile apparatus (as opposed to portable).
- A lowest frequency of operation being 880 MHz.
- The power into the antenna is measured to be 30 dBm.
- The antenna gain is 0 dBi
- The limit for Power Density (S) is selected for compliance for General Population and Uncontrolled Exposure which relates to:
  - S = f / 1500 mW/cm^2
  - For 880 MHz S = 880 / 1500 = 0.587 = 0.6 mW/cm^2 (Which would be the worst case over the transmitter operating range of 880 to 925 MHz even though it's a smaller number (see R equation below)).
  - The value of S directly relates to the MPE (Maximum Permissible Exposure) limit set forth by FCC OET-65.

Using the FCC supplied equation for Power Density (S):

$$S = \frac{P*G}{4*\pi*R^2}$$

(Equation 1) [1]

Where:

P = 30 dBm = (10$^{(30/10)}$ * 001) = 1.00 Watts = 1000 mW

G = 0 dBi = 10$^{(0/10)}$ = 1.0 (Numeric)

R = Distance to Center Of Radiation of the Antenna in cm.

S = 0.6 mW/cm^2

R = SQRT((P*G)/(4*π*S))

R = SQRT((1000*1)/(4*3.14*0.6)) = 11.6 cm => 12 cm (Rounded)

Solving for R would give a separation distance of 12 centimeters to meet the MPE limit of 0.6 mW/cm^2 if the transmitter was in *continuous* operation which is not the case. The 12 cm separation is well within the 20 cm limit that the FCC mandates for mobile operation as stated on the grant of equipment authorization for the transmitter. (12 cm = 4.73 Inches)

A copy of the MPE clause from the gas meter grant of equipment authorization is shown below (for continuous operation):

> Modular Approval. Power listed is conducted. This Modular Approval is limited to OEM installation for mobile and fixed applications only. The antenna gain must not exceed 0dBi. The antenna(s) used for this transmitter must be installed to provide a separation distance of at least 20 cm from all persons and must not be co-located or operating in conjunction with any other antenna or transmitter. Users and installers must be provided with antenna installation instructions and transmitter operating conditions for satisfying RF exposure

1. FCC OET Bulletin 65, Edition 97-01. August 97. Equation 3, Page 19

FCC OET-65 allows for time averaging power density over a period of 30 minutes for installations that apply to general population and uncontrolled exposure. Using the equations provided in OET-65 we may determine the average power density (S) that would be encountered by the general population over a 30 minute time interval and relate that to a minimum distance that should be maintained from the transmitter antenna.

(From FCC OET-65) The sum of the product of the exposure levels and the allowed times for exposure must equal the product of the appropriate time averaging interval:

$$\sum S_{exp}\, t_{exp} = S_{limit}\, t_{avg}$$

(Equation 2)[2]

Where:

- S_{exp} = power density level of exposure (mW/cm^2)
- S_{limit} = appropriate power density MPE limit (mW/cm^2)
- t_{exp} = allowable time of exposure for (S_{exp})
- t_{avg} = appropriate MPE averaging time.

For our application the MPE limit is 0.6 mW/cm^2 and the time period allowed for time averaging is 30 minutes (from OET-65 for general population and uncontrolled exposure). Thus the right hand side of the equation becomes (in seconds):

$S_{limit}\, t_{avg}$ = 0.6 mW/cm^2 * 30 Minutes * 60 Seconds = 1080 mW-sec / cm^2

For gas meter, there are several transmission types that may be generated by the endpoint. The transmission type that has the potential of generating the highest number of RF emissions over the averaging intervals the FCC uses for MPE calculations is the “boost mode”.

The endpoint cannot continuously generate transmissions as the energy used to generate those transmissions is limited by the endpoint battery capacity. The battery can store enough energy to allow the endpoint to transmit an RF messages once every 6 seconds. (Note: Circuitry on the endpoint ensures that the battery is monitored for sufficient capacity before the transmitter is allowed to transmit again.)

Under normal operation of the meter, the transmitter should never obtain a duty cycle of one transmitted messages every 6 seconds. The worst case scenario for transmitter operation will occur when the unit is originally commissioned and the transmitter is set to operate in “boost mode”.

The fastest rate at which any given gas meter transmitter can transmit is once every 6 seconds. Using boost mode, the transmitter is on-air for 1.2 seconds. The longest repetition of transmissions occurs during commissioning of the transmitter (at installation time). The number of transmit repetitions used for a gas meter installation is 31. Over the installed life of the transmitter, the unit will never achieve a state where it will transmit more often and with as great of repetition as it does when commissioned. Normally, the transmitter will transmit no more than once every 15 minutes (usually this rate is on the order of once every 4 hours or greater). Thus, commissioning with the unit operating in boost mode will be the basis of the following calculations.

2. FCC OET Bulletin 65, Edition 97-01, August 97. Equation 2, Page 11

RF Message Length Transmitting Boost Mode:	1200 milliseconds
Safeguard Interval Between Transmissions to Ensure Proper Battery Loading	6 Seconds
Thus, 1 Messages may be transmitted in [6 + (.107 * 2)] =	6 Seconds
Time Averaging Window For Uncontrolled Population Per OET-65:	30 Minutes
Number Of Messages That May Be Transmitted In 30 Minutes:	31
Total On Air Time Over 30 Minutes:	37.2 Seconds [31 * 1.2 Seconds Per Message]

NOTE: This number of messages would only occur if the meter were to be commissioned in one 30 minute interval.

Solving Equation 2 for S_{exp} using a total on air time of 37.2 seconds yields a value of:

$S_{exp} = (S_{limit}\ t_{avg})/\ t_{exp}$ = (1080 mW-sec / cm^2) / (37.2 seconds) = 29.0 mW/cm^2

To determine what distance would be required to generate this exposure limit we need to refer to Equation 1 and solve for the distance R:

R = SQRT((P*G)/(4*π*S))

R = SQRT((1000*1)/(4*3.14**29.0*)) = 1.65 cm

R = 1.65 cm / 2.54 cm/inch = .65 inches

The antenna on the endpoint is under a plastic housing which houses the meter register. The printed circuit board distance from the face of the plastic housing is 0.5 inches minimum. The center of radiation for the antenna used in the gas meter is not at the edge of the printed circuit board and is offset from the edge by more than 0.5 inches. Given this separation, the distance of 0.65 inches is well within the confines of the plastic package when the transmitter circuit board is mounted on a gas meter.

2.3 Summary for Uncontrolled Exposure

With the endpoint transmitting as many messages as is theoretically possible due to system design between messages, the MPE limits for general population / uncontrolled exposure would be met in all cases, as the distance from the center of the antenna peak radiation on the endpoint is far enough away from the plastic housing which covers it so that an installer would never achieve the minimum distance of 0.65 inches (and then, only if the unit is commissioned in boost mode.

2.4 MPE Calculations for Occupational/Controlled Exposure

Given

- The transmitter is considered a mobile apparatus (as opposed to portable).
- A lowest frequency of operation being 880 MHz.
- The power into the antenna is measured to be 30 dBm.
- The antenna gain is 0 dBi
- The limit for Power Density (S) is selected for compliance for Occupational / Controlled Exposure which relates to:
  - o S = f / 300 mW/cm^2
  - o For 880 MHz S = 880 / 300 = 2.93333 = 2.93 mW/cm^2 (Which would be the worst case over the transmitter operating range of 880 to 925 MHz even though it's a lower number (see R equation below).)
  - o The value of S directly relates to the MPE (Maximum Permissible Exposure) limit set forth by FCC OET-65.

Using the FCC supplied equation for Power Density (S):

$$S = \frac{P*G}{4*\pi*R^2}$$

(Equation 1)[3]

Where:

P = 30 dBm = ($10^{(30/10)}$ * 001) = 1.00 Watts = 1000 mW

G = 0 dBi = $10^{(0/10)}$ = 1.0 (Numeric)

R = Distance To Center Of Radiation Of The Antenna In cm.

S = 2.93 mW/cm^2

R = SQRT((P*G)/(4*π*S))

R = SQRT((1000*1)/(4*3.14*2.93)) = 5.21 cm

Solving For R would give a separation distance of 5.2 centimeters to meet the MPE limit of 2.93 mW/cm^2 if the transmitter was in *continuous* operation which is not the case. The 5.2 cm separation is well within the 20 cm limit that the FCC mandates for mobile operation as stated on the grant of equipment authorization for the transmitter.

FCC OET-65 allows for time averaging power density over a period of 6 minutes for installations that apply to Occupational and Controlled Exposure. Using the equations provided in OET-65 (page 11) we may determine the average power density (S) that would be encountered over a 6 minute time interval and relate that to a minimum distance that should be maintained from the transmitter antenna.

3. FCC OET Bulletin 65, Edition 97-01. August 97. Equation 3, Page 19

(From FCC OET-65) The sum of the product of the exposure levels and the allowed times for exposure must equal the product of the appropriate time averaging interval:

$$\sum S_{exp}\, t_{exp} = S_{limit}\, t_{avg}$$

(Equation 2)[4]

Where:

- S_{exp} = power density level of exposure (mW/cm^2)
- S_{limit} = appropriate power density MPE limit (mW/cm^2)
- t_{exp} = allowable time of exposure for (S_{exp})
- t_{avg} = appropriate MPE averaging time.

For our application the MPE limit is 2.93 mW/cm^2 and the time period allowed for time averaging is 6 minutes (from OET-65 for occupational and controlled exposure). Thus the right hand side of the equation becomes (in seconds):

$S_{limit}\, t_{avg}$ = 2.93 mW/cm^2 *6 Minutes*60 Seconds = 1054.8 mW-sec / cm^2

For gas meter, there are several transmission types that may be generated by the endpoint. The transmission type that has the potential of generating the highest number of RF emissions over the averaging intervals the FCC uses for MPE calculations is the “boost mode”.

The endpoint cannot continuously generate transmissions as the energy used to generate those transmissions is limited by the endpoint battery capacity. The battery can store enough energy to allow the endpoint to transmit an RF messages once every 6 seconds. (Note: Circuitry on the endpoint ensures that the battery is monitored for sufficient capacity before the transmitter is allowed to transmit again.)

Under normal operation of the meter, the transmitter should never obtain a duty cycle of one transmitted messages every 6 seconds. The worst case scenario for transmitter operation will occur when the unit is originally commissioned and the transmitter is set to operate in “boost mode”.

The fastest rate at which any given gas meter transmitter can transmit is once every 6 seconds. Using boost mode, the transmitter is on-air for 1.2 seconds. The longest repetition of transmissions occurs during commissioning of the transmitter (at installation time). The number of transmit repetitions used for a gas meter installation is 31. Over the installed life of the transmitter, the unit will never achieve a state where it will transmit more often and with as great of repetition as it does when commissioned. Normally, the transmitter will transmit no more than once every 15 minutes (usually this rate is on the order of once every 4 hours or greater). Thus, commissioning with the unit operating in boost mode will be the basis of the following calculations.

4. FCC OET Bulletin 65, Edition 97-01, August 97. Equation 2, Page 11

RF Message Length Transmitting Boost Mode:	1200 milliseconds
Safeguard Interval Between Transmissions to Ensure Proper Battery Loading	6 Seconds
Thus, 1 Messages may be transmitted in [6 + (.107 * 2)] =	6 Seconds
Time Averaging Window For Uncontrolled Population Per OET-65:	6 Minutes
Number Of Messages That May Be Transmitted In 30 Minutes:	31
Total On Air Time Over 30 Minutes:	37.2 Seconds [31 * 1.2 Seconds Per Message]

NOTE: This number of messages would only occur if the meter were to be commissioned in one 30 minute interval.

Solving Equation 2 for S_{exp} using a total on air time of 61.85 seconds and the S limit for occupational/ controlled exposure yields a value of:

$S_{exp} = (S_{limit}\ t_{avg})/\ t_{exp}$ = (1054.8 mW-sec / cm^2) / (37.2 seconds) = 28.4 mW/cm^2

To determine what distance would be required to generate this exposure limit we need to refer to Equation 1 and solve for the distance R:

R = SQRT((P*G)/(4*π*S))

R = SQRT((1000*1)/(4*3.14**28.4*)) = 1.67 cm

R = 1.67 cm / 2.54 cm/inch = .66 inches

2.5 Summary for Controlled Exposure

With the endpoint transmitting as many messages as is theoretically possible due to system design between messages, the MPE limits for occupational / controlled exposure would be met in all cases, as the distance from the center of the antenna peak radiation on the endpoint is far enough away from the plastic housing which covers it so that an installer would never achieve the minimum distance of 0.66 inches (and then, only if the unit is commissioned in boost mode).