microSplatch™ uSP410 Series Ground Plane Optimization

The Linx Technologies microSplatch™ uSP410 series embedded 1/4-wave monopole antennas require a ground plane on the printed circuit board (PCB) to which they are mounted. Linx recommends a 38 mm x 84 mm or larger ground plane, but other size ground planes may be used with proper design considerations as described in this application note. Please refer to the uSP410 series datasheets for other design requirements for the uSP410 series or contact Linx for a complimentary design review to help optimize solution performance.

Application Overview

This application note presents simulated performance results for the 433 MHz, 868 MHz and 915 MHz uSP410 antennas on ground plane sizes ranging in length from 40 mm to 120 mm as well as test data from the 84 mm x 38 mm evaluation board.

Table 1. Simulated Performance on Various Ground Plane Sizes

	ANT-433-uSP410			ANT-868-uSP410			ANT-915-uSP410		
Ground Plane Length	VSWR	Peak Gain	Efficiency	VSWR	Peak Gain	Efficiency	VSWR	Peak Gain	Efficiency
120 mm	2.1	-5.9	6	1.7	3.8	36	1.7	4.1	47
100 mm	1.9	-6.7	5	2.0	1.8	24	1.8	1.9	32
84 mm*	2.2	-8.0	5	2.1	0.7	20	2.7	0.9	27
80 mm	1.7	-8.9	4	2.1	-0.7	16	3.0	-0.3	21
60 mm	1.5	-10.5	4	2.2	-2.8	11	3.0	-2.7	13
40 mm	1.7	-12.3	3	2.2	-5.5	8	4.2	-5.0	10

*Actual test data on linx evaluation board

Ground Plane Requirements

Reducing the ground plane size narrows the bandwidth of the antenna at lower frequencies. This is most noticeable in the VSWR performance. The use of matching networks allows VSWR to be optimized for the ground plane conditions but cannot completely account for a ground plane that is too small for target frequencies.

In theory, the minimum ground plane size for any 1/4-wave monopole antenna is determined by its guided 1/4 wavelength, $\lambda_g/4$. This guided wavelength will be based on the 1/4 wavelength of the lowest frequency supported by the antenna, but will be restricted – lengthened – by the material through which the antenna signal propagates. For the uSP410 series, the guided wavelength is defined by the FR4 material from which the antenna is constructed and should be greater than or equal to 84 mm. In practice it is also important to provide some margin greater than the guided wavelength for the ground plane size to account for electromagnetic fringing effects at the PCB edges.

There is no limitation on how large a ground plane may be in support of a monopole antenna and a larger ground plane will improve antenna performance.

Comparing Antenna Performance

When comparing performance of the uSP410 series against other antennas or across varying lengths of ground plane it is important to review more than just VSWR (See the uSP410 series datasheets and definitions provided at the end of this application note). The peak gain and efficiency of the antenna also reflect the performance that can be expected in an end-solution.

In addition to simply reviewing charts of VSWR, gain and efficiency, it may also be valuable to calculate the total radiated efficiency (TRE) of the antenna at important frequencies. By reviewing individual parameters and TRE, a more complete comparison of likely performance can be achieved.

The uSP410 series Antenna Evaluation Kit shown in Figure 1 displays the ground plane size for the evaluation board as well as ground plane sizes for 40 mm, 60 mm, 80 mm, 100 mm and 120 mm lengths addressed in this application note. The 38 mm dimension represents the width of the ground plane. The uSP410 series antennas require that no ground plane or traces be located under the antenna area so additional space is required on the PCB for the antenna.

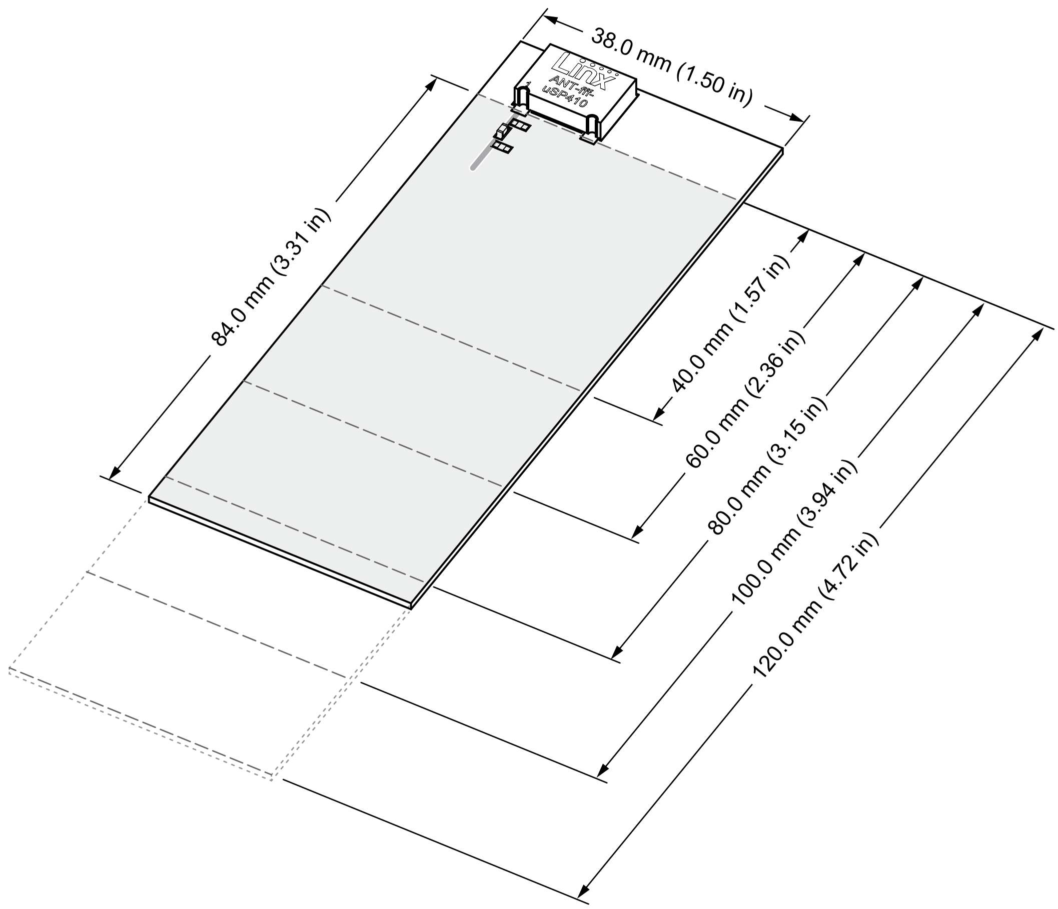

Figure 1. uSP410 Series Evaluation PCB with Various Ground Plane Sizes

ANT-433-uSP410

433 MHz microSplatch antenna simulated data is shown in Figure 2 through Figure 4 including actual test data using the Linx uSP410 evaluation board (38 mm x 84 mm) as a reference.

The charts on the following pages display typical behavior of the 433-uSP410 antenna when used on a PCB that has a ground plane area greater, or smaller than the 38 mm x 84 mm recommended size. PCB's with ground plane areas smaller than the recommended ground plane size indicate a shift towards higher frequencies, and experience a wider bandwidth resulting in higher VSWR and lower gain and efficiency, while a larger ground plane shifts downward in frequency and the bandwidth narrows, improving gain and efficiency.

Ground Plane Length (ANT-433-uSP410)	VSWR	Peak Gain (dBi)	Efficiency (dBi)
120 mm x 38 mm	2.1	-5.9	6
100 mm x 38 mm	1.9	-6.7	5
84 mm x 38 mm*	2.2	-8.0	5
80 mm x 38 mm	1.7	-8.9	4
60 mm x 38 mm	1.5	-10.5	4
40 mm x 38 mm	1.7	-12.3	3

* actual test data using Linx uSP410 evaluation board

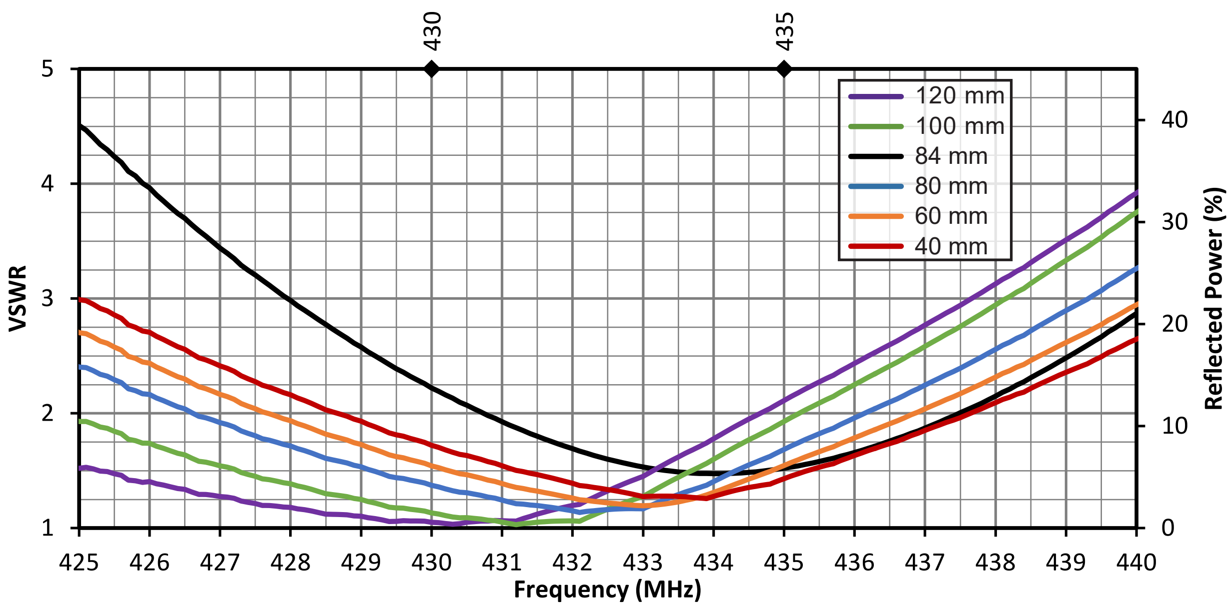

Figure 2. ANT-433-uSP410 VSWR

ANT-433-uSP410

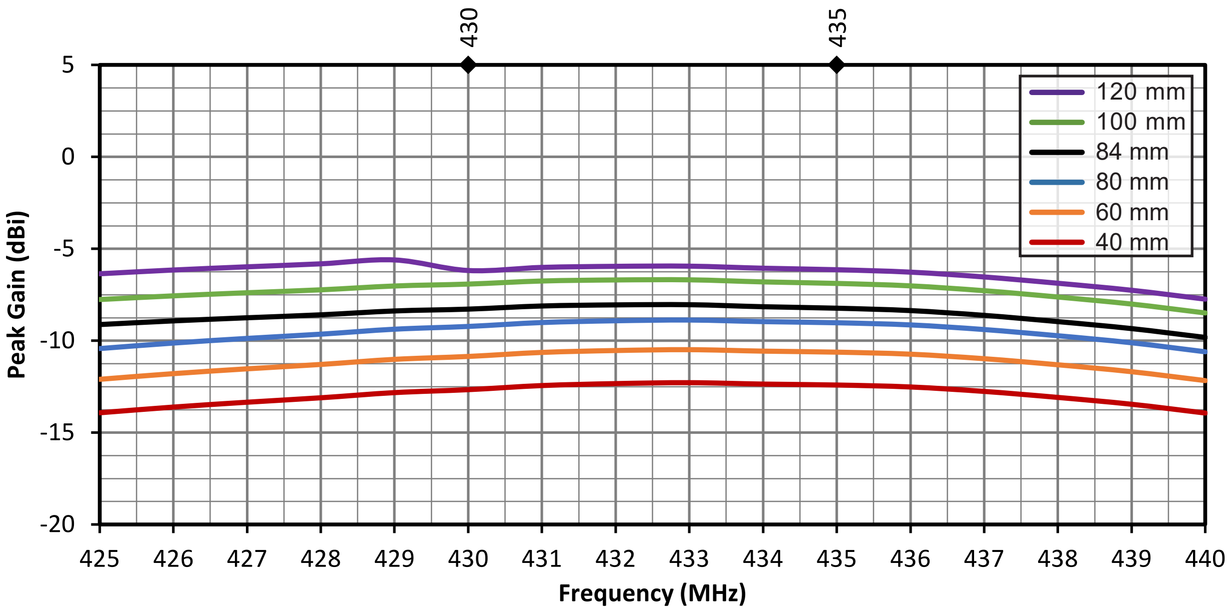

Figure 3. ANT-433-uSP410 Peak Gain

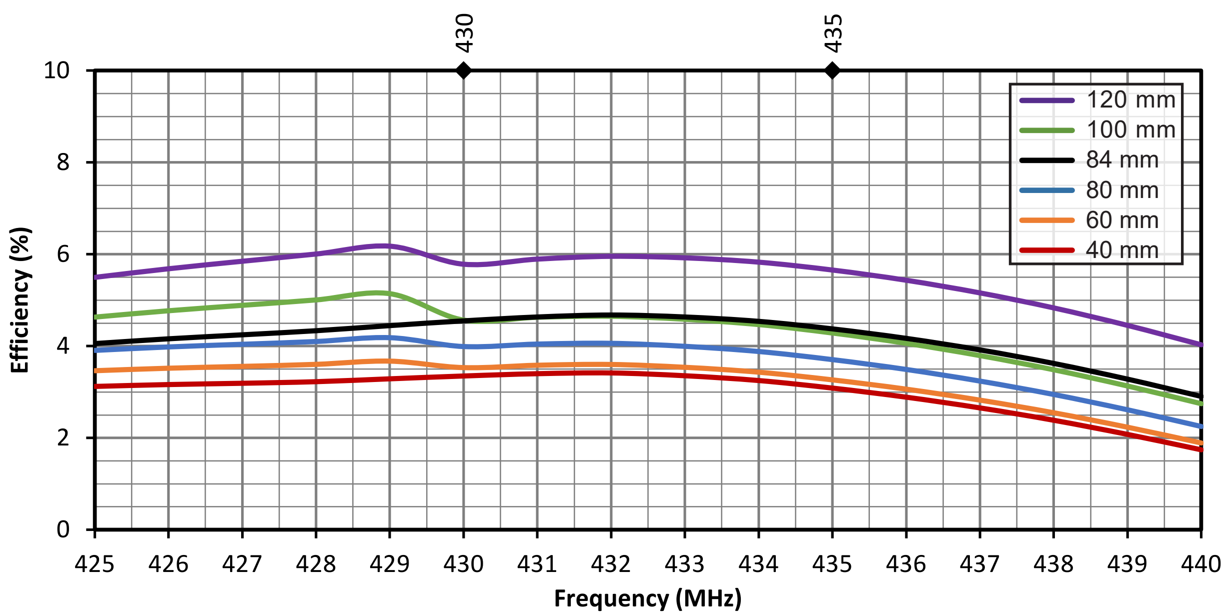

Figure 4. ANT-433-uSP410 Radiation Efficiency

ANT-868-uSP410

868 MHz microSplatch antenna simulated data is shown in Figure 5 through Figure 7 including actual test data using the Linx uSP410 evaluation board (38 mm x 84 mm) as a reference.

The charts on the following pages display typical behavior of the 868-uSP410 antenna when used on a PCB that has a ground plane area greater, or smaller than the 38 mm x 84 mm recommended size. PCB's with ground plane areas smaller than the recommended ground plane size indicate a shift towards higher frequencies, and experience a wider bandwidth resulting in higher VSWR and lower gain and efficiency, while a larger ground plane shifts downward in frequency and the bandwidth narrows, improving gain and efficiency.

Ground Plane Length (ANT-868-uSP410)	VSWR	Peak Gain (dBi)	Efficiency (dBi)
120 mm x 38 mm	1.7	3.8	36
100 mm x 38 mm	1.9	1.8	24
84 mm x 38 mm*	2.1	0.7	20
80 mm x 38 mm	2.3	-0.7	16
60 mm x 38 mm	2.6	-2.8	11
40 mm x 38 mm	2.7	-5.5	8

* actual test data using Linx uSP410 evaluation board

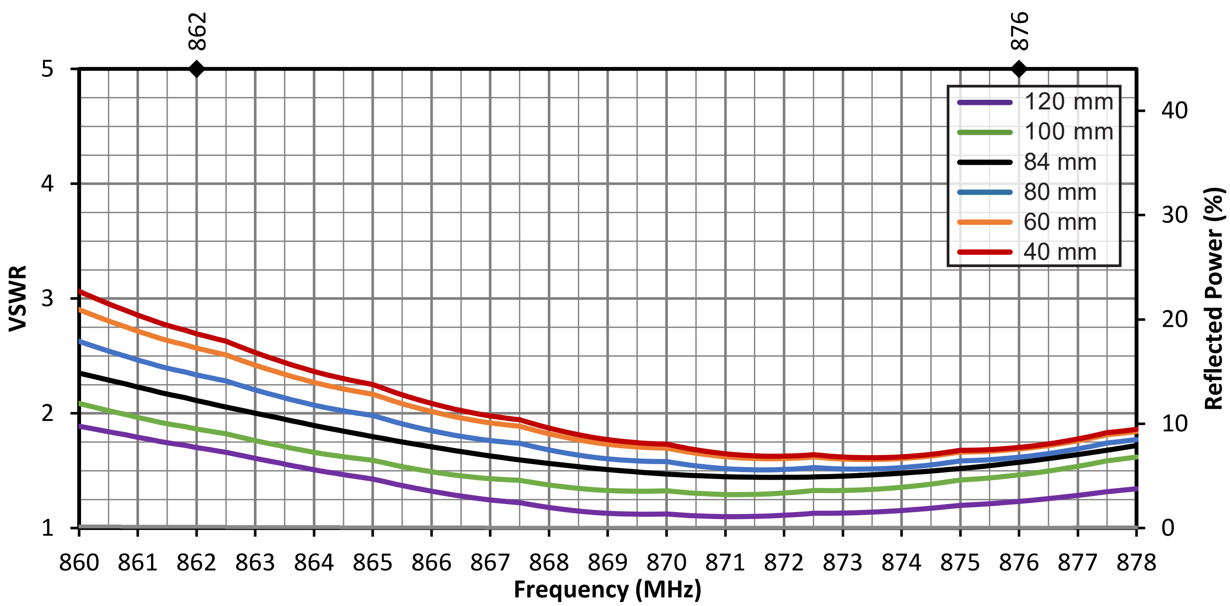

Figure 5. ANT-868-uSP410 VSWR

ANT-868-uSP410

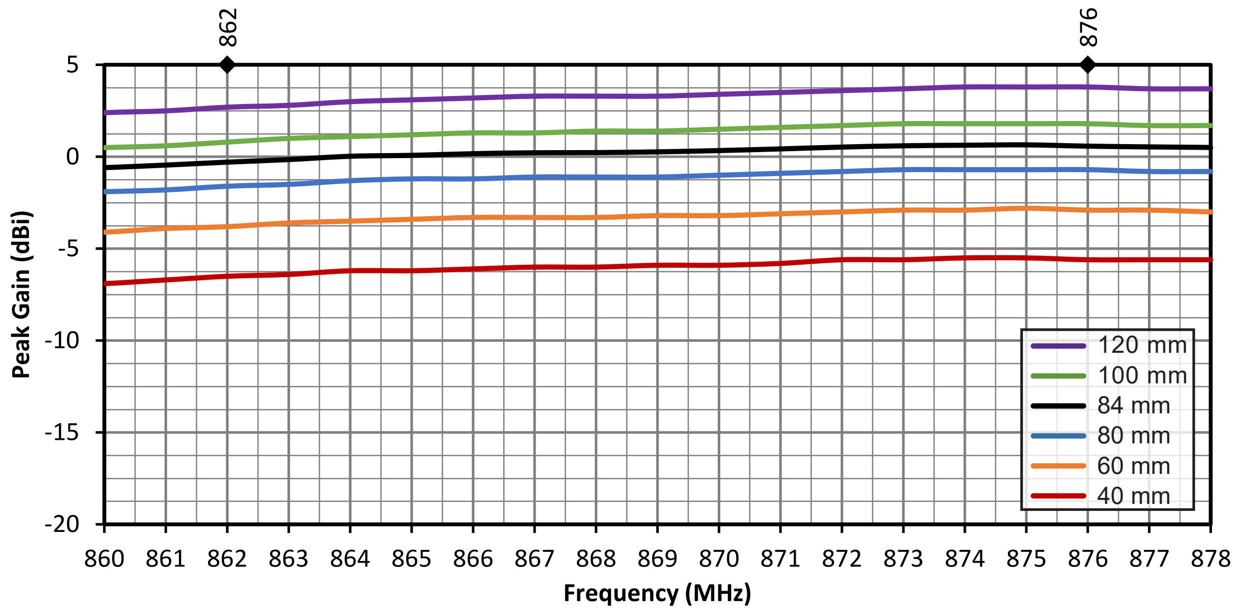

Figure 6. ANT-868-uSP410 Peak Gain

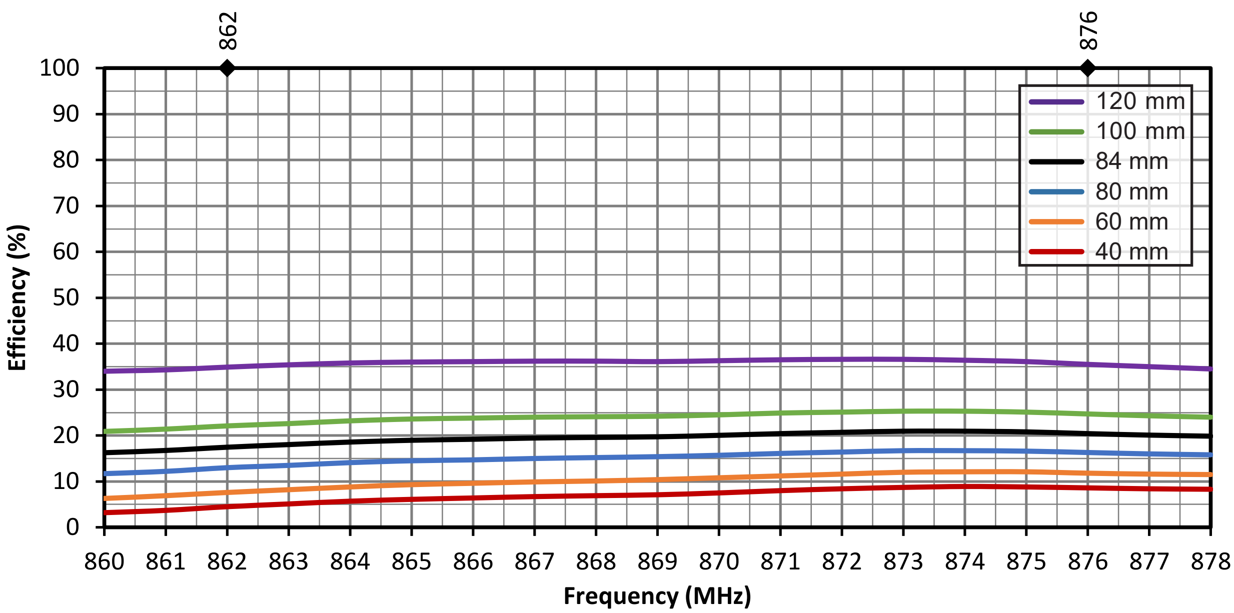

Figure 7. ANT-868-uSP410 Radiation Efficiency

ANT-915-uSP410

915 MHz microSplatch antenna simulated data is shown in Figure 8 through Figure 10 including actual test data using the Linx uSP410 evaluation board (38 mm x 84 mm) as a reference.

The charts on the following pages display typical behavior of the 915-uSP410 antenna when used on a PCB that has a ground plane area greater, or smaller than the 38 mm x 84 mm recommended size. PCB's with ground plane areas smaller than the recommended ground plane size indicate a shift towards higher frequencies, and experience a wider bandwidth resulting in higher VSWR and lower gain and efficiency, while a larger ground plane shifts downward in frequency and the bandwidth narrows, improving gain and efficiency.

Ground Plane Length (ANT-915-uSP410)	VSWR	Peak Gain (dBi)	Efficiency (dBi)
120 mm x 38 mm	1.7	4.1	47
100 mm x 38 mm	1.8	1.9	32
84 mm x 38 mm*	2.7	0.9	27
80 mm x 38 mm	3.0	-0.3	21
60 mm x 38 mm	3.0	-2.7	13
40 mm x 38 mm	4.2	-5.0	10

* actual test data using Linx uSP410 evaluation board

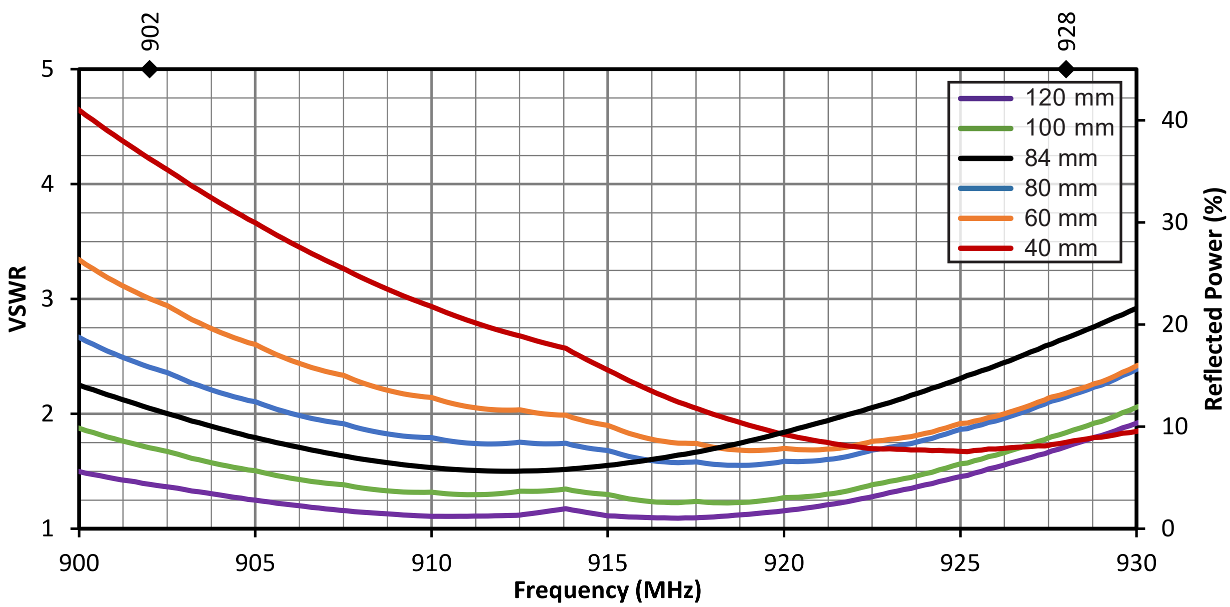

Figure 8. ANT-915-uSP410 VSWR

ANT-915-uSP410

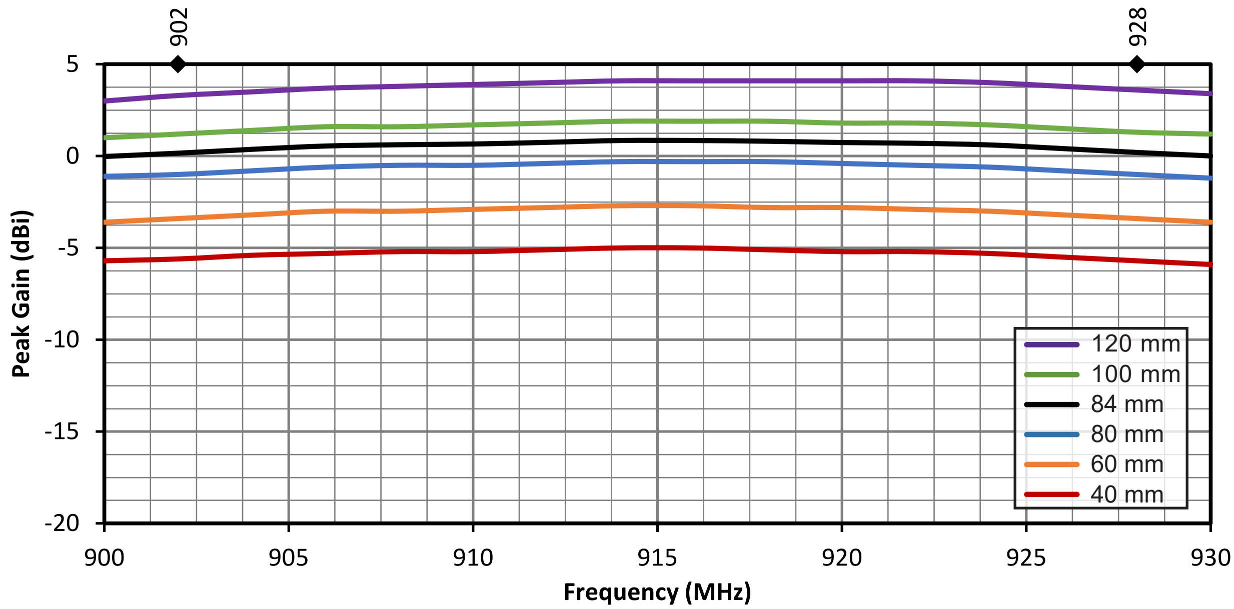

Figure 9. ANT-915-uSP410 Peak Gain

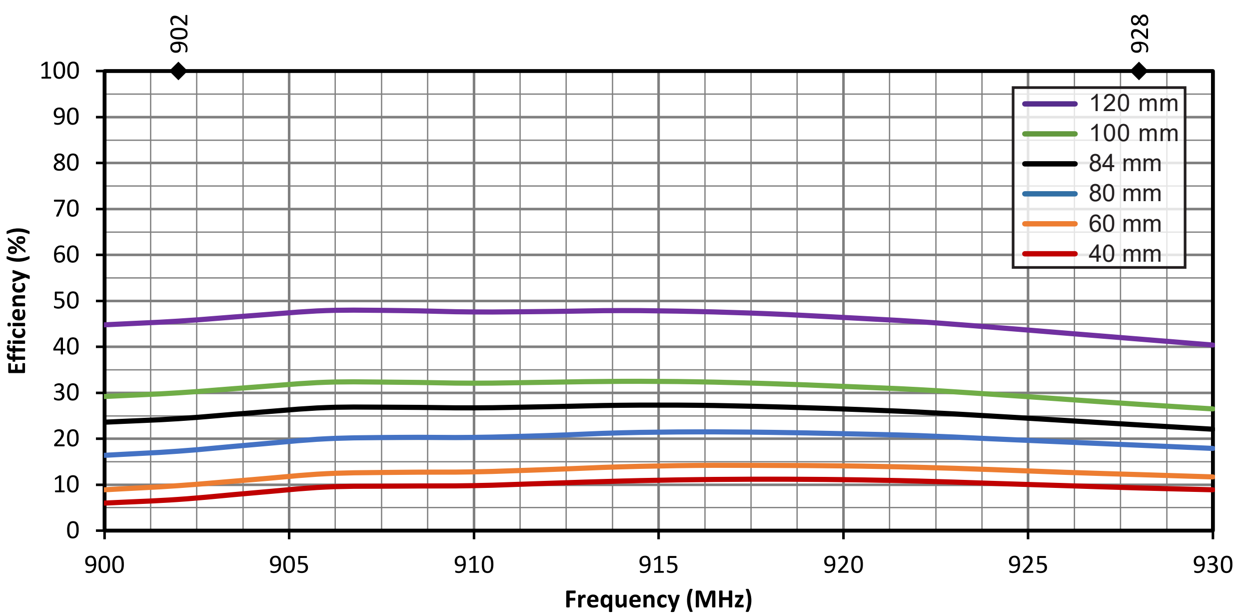

Figure 10. ANT-915-uSP410 Radiation Efficiency

Antenna Definitions and Useful Formulas

VSWR - Voltage Standing Wave Ratio. VSWR is a unitless ratio that describes the power reflected from the antenna back to the radio. A lower VSWR value indicates better antenna performance at a given frequency. VSWR is easily derived from Return Loss.

$$\mathrm{VSWR} = \frac{10^{\left[\frac{\mathrm{Return\ Loss}}{20}\right]} + 1}{10^{\left[\frac{\mathrm{Return\ Loss}}{20}\right]} - 1}$$

Return Loss - Return loss represents the loss in power at the antenna due to reflected signals, measured in decibels. A lower return loss value indicates better antenna performance at a given frequency. Return Loss is easily derived from VSWR.

$$\mathrm{Return\ Loss} = -20\log_{10}\left[\frac{\mathrm{VSWR}-1}{\mathrm{VSWR}+1}\right]$$

Efficiency (η) - The total power radiated from an antenna divided by the input power at the feed point of the antenna as a percentage.

Total Radiated Efficiency - (TRE) The total efficiency of an antenna solution comprising the radiation efficiency of the antenna and the transmitted (forward) efficiency from the transmitter.

$$\mathrm{TRE} = \eta \bullet \left(1 - \left(\frac{\mathrm{VSWR}-1}{\mathrm{VSWR}+1}\right)^2\right)$$

Gain - The ratio of an antenna's efficiency in a given direction (G) to the power produced by a theoretical lossless (100% efficient) isotropic antenna. The gain of an antenna is almost always expressed in decibels.

$$G_{db} = 10\log_{10}(G)$$

$$G_{dBd} = G_{dBi} - 2.51\mathrm{dB}$$

Peak Gain - The highest antenna gain across all directions for a given frequency range. A directional antenna will have a very high peak gain compared to average gain.

Average Gain - The average gain across all directions for a given frequency range.

Maximum Power - The maximum signal power which may be applied to an antenna feed point, typically measured in watts (W).

Reflected Power - A portion of the forward power reflected back toward the amplifier due to a mismatch at the antenna port.

$$\left(\frac{\mathrm{VSWR}-1}{\mathrm{VSWR}+1}\right)^2$$

decibel (dB) - A logarithmic unit of measure of the power of an electrical signal.

decibel isotropic (dBi) - A comparative measure in decibels between an antenna under test and an isotropic radiator.

decibel relative to a dipole (dBd) - A comparative measure in decibels between an antenna under test and an ideal half-wave dipole.

Dipole - An ideal dipole comprises a straight electrical conductor measuring 1/2 wavelength from end to end connected at the center to a feed point for the radio.

Isotropic Radiator - A theoretical antenna which radiates energy equally in all directions as a perfect sphere.

Omnidirectional - Term describing an antenna radiation pattern that is uniform in all directions. An isotropic antenna is the theoretical perfect omnidirectional antenna. An ideal dipole antenna has a donut-shaped radiation pattern and other practical antenna implementations will have less perfect but generally omnidirectional radiation patterns which are typically plotted on three axes.

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