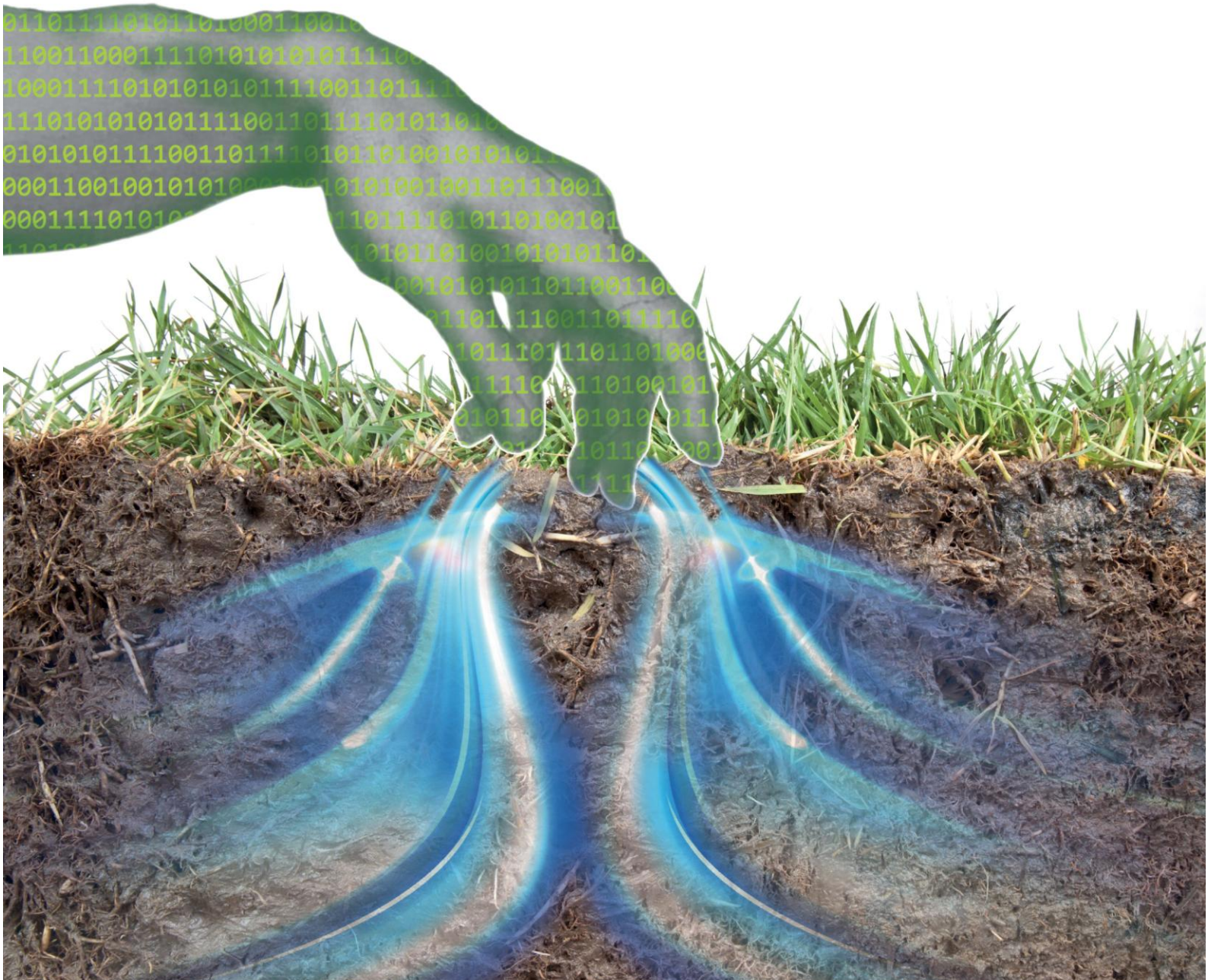
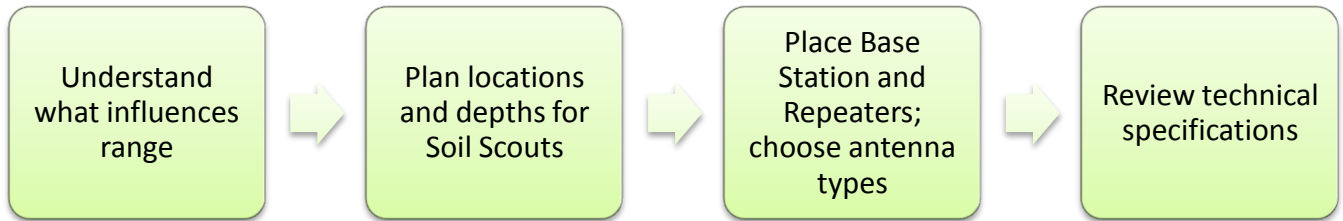


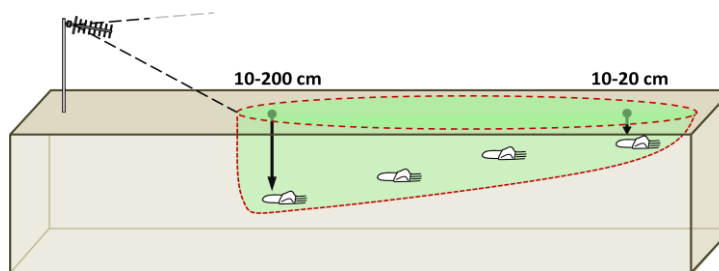
## RANGE, ANTENNA AND CABLE GUIDE



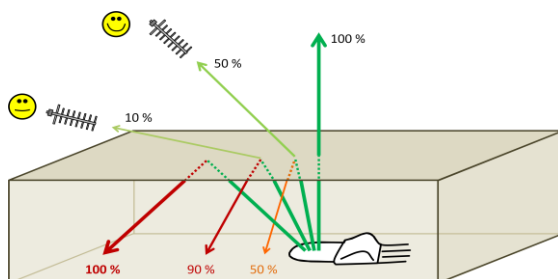
## Overview: Factors influencing Range

The range distance tables attached to this document will specify the maximum ranges that you can expect to reach with certain setups. Understanding the underlying attenuation phenomena will help you in making use of the tables.

<b>Depth</b>	<p>The thicker the soil layer between the Scout and open air is, the larger is the attenuation (loss) caused by the soil layer absorbing radio signal power.</p> <p>Place the receiver close to the deepest Scouts to compensate for higher attenuation.</p>
<b>Soil Type</b>	<p>Coarse (sandy) soils textures attenuate signals less than finer (clayey) soils. Clay content is the key property defining the soil's attenuation factor. Clay contents of less than &lt;10 % are low, while contents exceeding &gt;40 % are high.</p> <p>Exceptionally high clay contents exceeding &gt;70 % will cause severe attenuation when the soil is wet, and the range and/or depth expectations must be cut back. Note that in certain cases, an ECHO repeater will assist in extending reception range.</p>
<b>Soil Moisture</b>	<p>Water in the soil pores is the most important factor causing attenuation inside the soil layer. Dry soil absorbs less radio signal power than moist or wet soils.</p> <p>As wet soil conditions reduce transmission distances, it is important to take this into account when installing. Please check the Wet Soil Range Estimation Table at the end of this document. Alternatively, you may choose to configure a wider setup, where the most distant Scouts are allowed to lose connectivity in wet conditions, if occasional data loss is not a significant issue.</p>
<b>Antenna Height</b>	<p>Install the Base Station receiving antenna as high as possible, taking into account that the higher the antenna, the greater the minimum distance is between the antenna and the nearest Scout (blind range). The minimum recommend antenna height at its base is 6 metres, with a preference for &gt;12 metres, depending on the need for extended reception distances.</p> <p>Elevating the antenna enhances range because it allows the underground signal to penetrate the soil surface at a higher outcoming angle, which reduces reflection back underground (depicted below).</p>
<b>Crop Type</b>	<p>Thick vegetation will absorb signal power. Different crops impact reception to varying degrees, largely based on their water content and density. Rain-soaked crops will temporarily decrease reception ranges more than normally.</p> <p>Place Scouts at varying distances from your receiver to allow for situations where thick vegetation will start cancelling connectivity to the most distant Scouts.</p>



*Place the receiver close to the deepest Scouts in order to balance between depth and distance.*

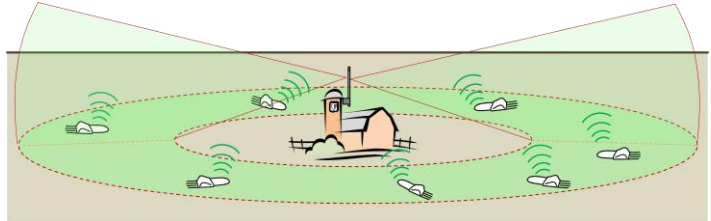


*If the receiving antenna stands low, the Scout signal is mostly reflected back underground. An elevated antenna allows the signal to penetrate the soil surface at a higher outcoming angle, which gives a stronger signal, since reflection becomes less dominant.*

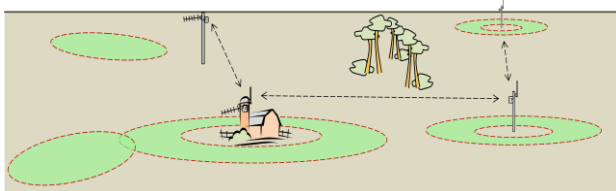
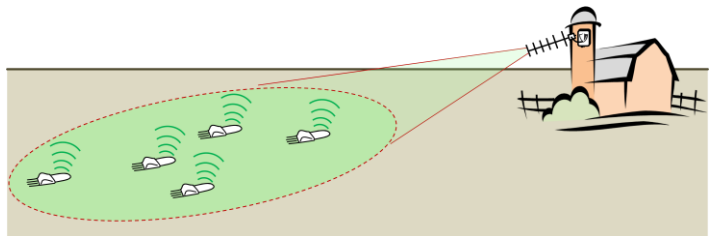
## Placing the Base Station and Repeaters, and Choosing the appropriate Antenna Type

The choice of receiving antenna type should be based on the geometry of your system, i.e. in which direction and how far from the Base Station you wish to place your Scouts, as well whether you will be using one or more ECHO repeater(s).

An **Omnidirectional Pole**, or Omni, is a stick shaped antenna, which is designed to receive signals from all horizontal directions, but not directly from up or down. This causes a *blind range* close to an elevated Omni antenna. The Omni allows for 360 degree horizontal reception, but the maximum receiving distances is less than a Yagi, for example.



A **Yagi** is a directional antenna, which gives radio signals a high gain (long range), but only in a narrow sector (90 degrees). The Yagi is good for receiving signals coming from the direction it is pointed, but will not receive from other directions.



**ECHO Repeaters** enable the placement of Scouts at much greater distances than using just a Base Station. In addition, ECHO Repeaters enable Scout transmissions to get around geographical obstacles such as thick vegetation, buildings and hills. The ECHO is a standalone solar-powered device, that relay's Scout signals back to the Base Station – either directly, or via other ECHO's.

**Stub Antennas** can be used in special cases, such as pile monitoring, where the the Scout and Base Station are very close to each other. A stub will receive signals spherically from all directions, but will not give any gain (boost) to the signal.

*Parabolic Dishes* can be used in the most challenging settings to pick up individual signals from very far away. Dishes are large in size and have a very narrow beam width (typically 7-9° wide sector) and thus require that all Scouts are buried in an precisely straight line from the dish. Note: not available from Soil Scout, but specifications are available upon request.

If you need further guidance, please contact a Soil Scout representative to discuss.

## Antenna Height and Tilt Angle Influence on Blind Ranges

### Omnidirectional Pole Antenna

An omnidirectional antenna will receive signals from all directions, but not from high or low angles. Also it has a low gain, so it will not receive signals from very far away.

For an omni with 6 dBi gain, the blind range, which the antenna overshoots, is approximately  $2 \times$  Antenna height.

*Example: Antenna height is 10 m, Blind range  $2 \times 10 \text{ m} = 20 \text{ m}$*

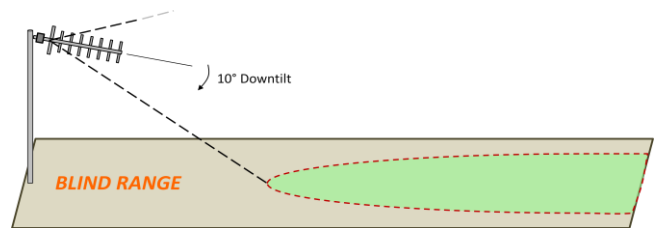


### Yagi

A yagi antenna should always tilt downwards at least  $10^\circ$  below horizon, since no signals arrive from above the horizon. It will only receive signals from the direction where it is pointing.

The blind range, which a Yagi overshoots is equal to Antenna height.

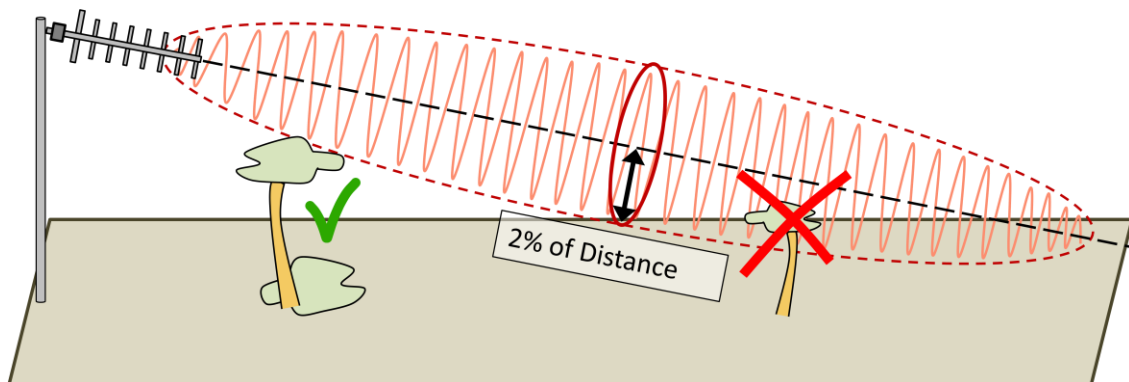
*Example: Antenna height is 12 m, Blind range is 12 m*



## Needed Clearance from the Line of Sight

Contrary to common understanding, a radio wave will not travel straight point-to-point in a narrow line of sight (LoS), but will in fact require a larger clear tubular space around the straight LoS, called *the Fresnel Zone*. Any obstacles standing close to the LoS will interfere with the radio wave and decrease signal power, resulting in poor connectivity.

At the wavelength that Soil Scout applies, the needed clearance radius is approximately 2% of the total range distance. The clearance requirement is highest halfway and thus a bit lower close to the antenna, but it is good practise to aim for the same clearance all along the line.



*Example:*

*Receiving antenna is 300 m away from the Scouts. Needed clearance is approximately 6 m from the center line.*

*If antenna is mounted at 10 m height, obstacles halfway the line should not be higher than 4 m.*

## Antenna and Cable Technical Specifications

Frequency in ITU-1 countries (Europe, Africa)	Typical antenna frequency range: 850-930 MHz. Centre frequency 869.5 MHz must be inside the band.
Frequency in ITU-2 countries (Americas, Australia)	Typical antenna frequency range: 890-960 MHz. Centre frequency 921.7 MHz must be inside the band.
Gain	<p>Low gain (1-3 dBi ) omnidirectional stub antennas rarely provide sufficient performance for a Base Station, but can be used for an ECHO Repeater if it is placed close to the Scouts.</p> <p>For short ranges (50 m) and shallow depths (30 cm) medium gain (6 dBi) is preferred, since a less directive antenna simplifies orientation and Scout placement.</p> <p>Otherwise, high gain (10-12 dBi) is better for receiving weak signals.</p>
Cable	<p>The longer the coaxial cable connecting the antenna to the Base Station gets, the more signal strength will be lost. Good quality 50Ω low-loss cables (0.2-0.3 dB/m @ 1GHz) must be used. Suggested cable types: LMR-240, LMR-400, RG-213/214, RG-142, 5D-FB (Chinese).</p> <p>The commonly used coaxial cable type RG-58 is not recommended.</p>
Connector	<p>The cable connector to the Base Station must be BNC-male (Base has female). Most commonly, the cable connector to receiving antennas is N-male (antennas have N-female), but naturally the cable must match the antenna that is chosen.</p> <p>Do not use connector adapters, since adapters significantly lose signal power.</p>

# SOIL SCOUT RANGE ESTIMATION TABLE

## Approximate Maximum Ranges for: WET SOIL



Base Station Antenna type and height

Soil texture	Depth	Omnidirectional Antenna				Directive Yagi Antenna				
		6 m	9 m	12 m	15 m	6 m	9 m	12 m	15 m	
Bare Ground	Sand	10 cm	410	490	550	610	590	720	820	910
		30 cm	330	400	450	490	490	590	680	750
		60 cm	250	290	320	350	360	440	500	560
		90 cm	180	210	220	240	270	330	370	410
	Loam	10 cm	340	400	450	500	490	590	680	760
		30 cm	180	210	230	240	270	330	370	410
		60 cm	60	40	40	50	110	130	150	160
		90 cm	15	20	25	25	40	50	50	50
	Clay	10 cm	320	380	430	470	470	570	650	720
		30 cm	150	180	190	200	240	280	320	360
		60 cm	25	30	40	40	80	100	110	110
		90 cm	10	5	5	5	25	25	25	30
1 m High Crop (Cereal)	Sand	10 cm	250	300	350	380	360	450	530	590
		30 cm	200	250	280	310	300	370	440	490
		60 cm	150	180	200	210	230	280	330	360
		90 cm	110	120	140	130	170	210	240	270
	Loam	10 cm	210	260	290	320	310	390	460	510
		30 cm	110	130	140	150	180	220	250	280
		60 cm	25	30	40	50	70	90	100	110
		90 cm	15	20	20	10	30	40	40	40
	Clay	10 cm	200	240	270	300	300	370	430	480
		30 cm	90	110	110	100	150	190	220	240
		60 cm	20	25	30	40	60	70	80	80
		90 cm	10	5	5	5	20	20	20	25
3 m High Crop (Corn)	Sand	10 cm	120	170	190	210	180	250	310	350
		30 cm	100	130	150	170	150	210	250	290
		60 cm	70	90	110	100	120	160	190	220
		90 cm	50	60	50	60	90	120	140	160
	Loam	10 cm	110	140	160	180	160	220	270	300
		30 cm	60	70	60	60	90	120	150	170
		60 cm	15	20	30	40	40	50	60	70
		90 cm	10	15	10	10	15	20	25	30
	Clay	10 cm	100	130	150	170	150	210	250	290
		30 cm	50	50	50	50	80	110	130	140
		60 cm	10	20	25	30	30	40	50	50
		90 cm	5	5	5	5	10	15	15	20

Sand: Clay 10% / Silt 50% / Sand 40%  
 Loam: Clay 20-30% / Silt 30-70% / Sand 10-40%  
 Clay: Clay 40% / Silt 30-40% / Sand 30-40%

**Note:**

- Estimates are presented for wet soil (50% volumetric moisture). Dry soils provide 30-40% better range
- Environmental conditions may reduce range temporarily (e.g. rainwater on crop, wet layer on dry soil...)
- Tree(s) and/or shrubs between Scout and Base may reduce the range by 50%
- In urban environments, background radio noise may hamper receiver sensitivity and decrease range by 10-20%
- Saline soils (4 dS/m and higher) or clay contents exceeding 60% will attenuate signals and lower achievable depth
- Lowering receiving antenna down to 3 m will cut the range approx. 40% compared to the 6 m height values

**Disclaimer:**

The information in this table is provided as an indicative planning guide, and is not a guarantee or warranty of performance under the stated conditions. Soil Scout Oy accepts no responsibility for errors or the inaccuracy of the information herein.

Updated 28 April 2017

## SOIL SCOUT RANGE ESTIMATION TABLE

### Approximate Maximum Ranges for: DRY SOIL



Base Station Antenna type and height

Soil texture	Depth	Omnidirectional Antenna				Directive Yagi Antenna				
		6 m	9 m	12 m	15 m	6 m	9 m	12 m	15 m	
Bare Ground	Sand	10 cm	450	540	610	670	640	780	890	1000
		30 cm	410	500	560	620	590	720	830	930
		60 cm	370	440	500	550	530	650	750	830
		90 cm	330	390	450	490	480	580	670	740
	Loam	10 cm	380	450	520	570	540	660	760	850
		30 cm	240	290	320	350	350	430	490	550
		60 cm	120	130	140	140	190	220	250	280
		90 cm	40	40	40	50	100	110	130	140
	Clay	10 cm	350	420	480	520	510	610	710	790
		30 cm	190	230	250	270	290	350	400	440
		60 cm	70	60	60	60	120	150	160	180
		90 cm	20	25	30	40	50	60	60	70
1 m High Crop (Cereal)	Sand	10 cm	300	380	430	480	440	550	650	730
		30 cm	280	350	400	440	410	520	600	670
		60 cm	250	310	350	390	370	460	540	600
		90 cm	220	280	310	350	330	420	480	540
	Loam	10 cm	270	340	390	430	400	500	590	660
		30 cm	170	210	240	260	260	330	380	420
		60 cm	80	90	80	80	140	170	190	220
		90 cm	25	30	40	50	70	90	100	110
	Clay	10 cm	250	310	350	390	370	460	530	600
		30 cm	140	160	180	190	210	260	300	340
		60 cm	40	40	40	50	90	110	120	140
		90 cm	15	20	25	30	40	40	50	50
3 m High Crop (Corn)	Sand	10 cm	150	210	240	270	220	310	380	430
		30 cm	140	190	230	250	210	290	350	400
		60 cm	130	170	200	220	190	260	310	360
		90 cm	110	150	170	190	170	230	280	320
	Loam	10 cm	140	190	220	240	200	280	340	390
		30 cm	90	110	130	140	130	180	220	250
		60 cm	40	40	40	50	70	100	110	130
		90 cm	15	20	30	40	40	50	60	70
	Clay	10 cm	130	170	200	220	190	260	310	360
		30 cm	70	90	90	80	110	150	180	200
		60 cm	15	25	30	40	50	60	70	80
		90 cm	10	15	20	20	20	25	30	40

*Sand: Clay 10% / Silt 50% / Sand 40%*  
*Loam: Clay 20-30% / Silt 30-70% / Sand 10-40%*  
*Clay: Clay 40% / Silt 30-40% / Sand 30-40%*

**Note:**

- Estimates are presented for dry soil (20% volumetric moisture). Wet soils provide 20-30% shorter range
- Environmental conditions may reduce range temporarily (e.g. rainwater on crop, wet layer on dry soil...)
- Tree(s) and/or shrubs between Scout and Base may reduce the range by 50%
- In urban environments, background radio noise may hamper receiver sensitivity and decrease range by 10-20%
- Saline soils (4 dS/m and higher) or clay contents exceeding 60% will attenuate signals and lower achievable depth
- Lowering receiving antenna down to 3 m will cut the range approx. 40% compared to the 6 m height values

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