Antenna Heights for 50 MHz Sporadic-E

Steve Kavanagh, VE3SMA

Introduction

Discussions of effects of antenna height over ground are commonly seen for the HF bands, but it is unusual to see one for the six metre band. This paper examines the significance of antenna height above ground at small 50 MHz stations, including Rovers, for single hop Sporadic-E propagation.

Geometry

The geometry of a Sporadic-E path is shown in Figure 1.

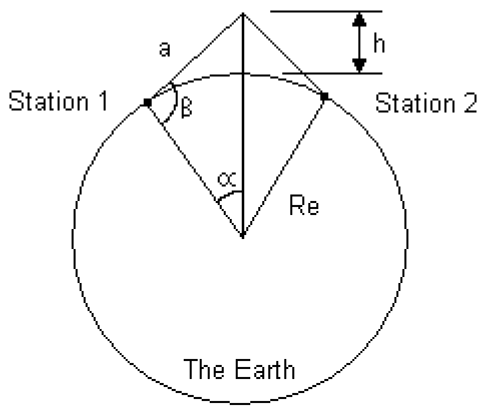

Figure 1: Sporadic-E Path Geometry

A very simple representation of the ionosphere is used, assuming that Sporadic E clouds behave like a horizontal mirror at an altitude h of 110 km above the Earth. The radius of the Earth R_e is 6378 km. The angle 2α represents the angle at the center of the Earth between the two ends of the path and β represents the angle between the line from the centre of the Earth to one station and the line of the path from that station up to the reflection point in the ionosphere. The elevation angle of the path above ground is β-90°. The following formulas are used. The distance along the Earth's surface between the two ends of the path is

$$D = 2\alpha R_e \text{ [for a in radians]} = \pi\alpha R_e/90 \text{ [for a in degrees]} .$$

From oblique triangle formulas, the path length from one station to the reflection point in the ionosphere is

$$a = \sqrt{(R_e+h)^2 + R_e^2 - 2R_e(R_e+h)\cos\alpha}$$

and the elevation angle of the path is given by

$$\text{Elev.} = \cos^{-1}[\,(R_e^2 + a^2 - (R_e+h)^2)/2R_e a\,] - 90° .$$

Elevation Angle vs. Distance

Using the above formulas the results shown in Table 1 and Figure 2 were computed for distances D of 1000 km and up. Most single hop Sporadic-E propagation on 6m falls into the distance range from in this table. Propagation over shorter paths is certainly not extremely unusual, but it is rarer. The maximum possible distance is computed to be 2352 km , where the elevation angle falls to zero. The actual maximum distance will depend somewhat on the actual height of the reflecting ionized cloud and whether an individual station has some advantage such as a QTH on a hill where negative elevation angles can be used, or good local tropospheric propagation that can extend the path.

It can be seen that to be able to work the maximum possible single hop distance it is necessary to have an antenna that works well at low elevation angles. From a contest perspective, it is interesting to consider the area on the Earth covered by ranges of elevation angles, and hence the relative number of contacts (and grids) that could be expected from an antenna that works well in that angular range. When this is done it is found that the area covered by elevation angles of 3 to 10 degrees (distances of 1000-1800 km) is about equal to that covered by elevation angles of 0 to 3 degrees (1800-2352 km).

Table 1: Elevation Angle vs. Distance for Sporadic-E

Distance D (km)	α (degrees)	Elevation Angle (degrees)
1000	4.4917	10.05
1100	4.9408	8.74
1200	5.3900	7.60
1300	5.8392	6.60
1400	6.2883	5.70
1500	6.7325	4.90
1600	7.1867	4.16
1700	7.6358	3.48
1800	8.0850	2.86
1900	8.5342	2.27
2000	8.9833	1.72
2100	9.4325	1.20
2200	9.8817	0.71
2300	10.3308	0.24
2352	10.5656	0.00

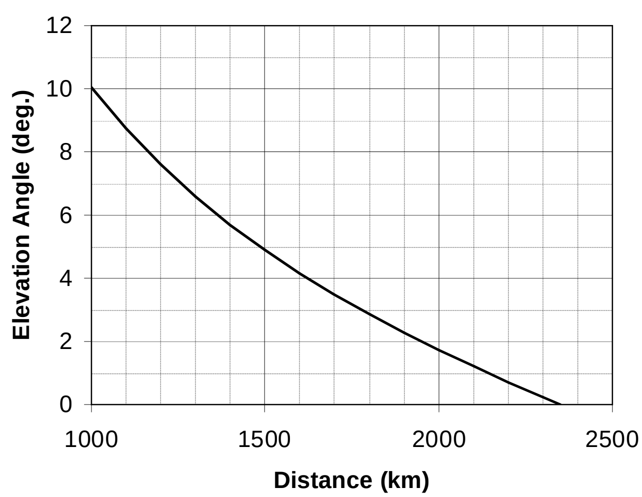

Figure 2: Elevation angle vs. Distance for Sporadic-E

Elevation Patterns of Simple Antennas

The Yagi modelling software that came with the ARRL Antenna Book, YA (by Brian Beezley, K6STI), was used to model the main beam radiation patterns of two simple 50 MHz antennas (a 3 element Yagi with 8.0 dBi gain, and a dipole) at various heights above ground. The main assumption here is that the ground is flat out to the point where the signal where a signal arriving at a given elevation angle reflects off the ground before reaching an antenna. This is quite a long way from the antenna (1145 feet for an antenna 40 feet high and an elevation angle of 2 degrees, for example), and so is unlikely to be entirely true for most locations. Additionally it is assumed that there are no obstructions blocking the path, which is also unlikely in practical locations. However, analysis of real situations is much more complicated and this simple approach will serve as a starting point.

The reflection from the ground has a 180 degree phase shift, for horizontal polarization, and as a result the reflection can add or subtract from the gain of the antenna in free space, depending on elevation angle and antenna height. The resulting computed patterns are shown in Figure 3 for elevation angles of 0.5-10 degrees. For comparison, one case is computed for a 3 element Yagi over ground which is flat but sloping at 5 degrees, downwards toward the direction of interest.

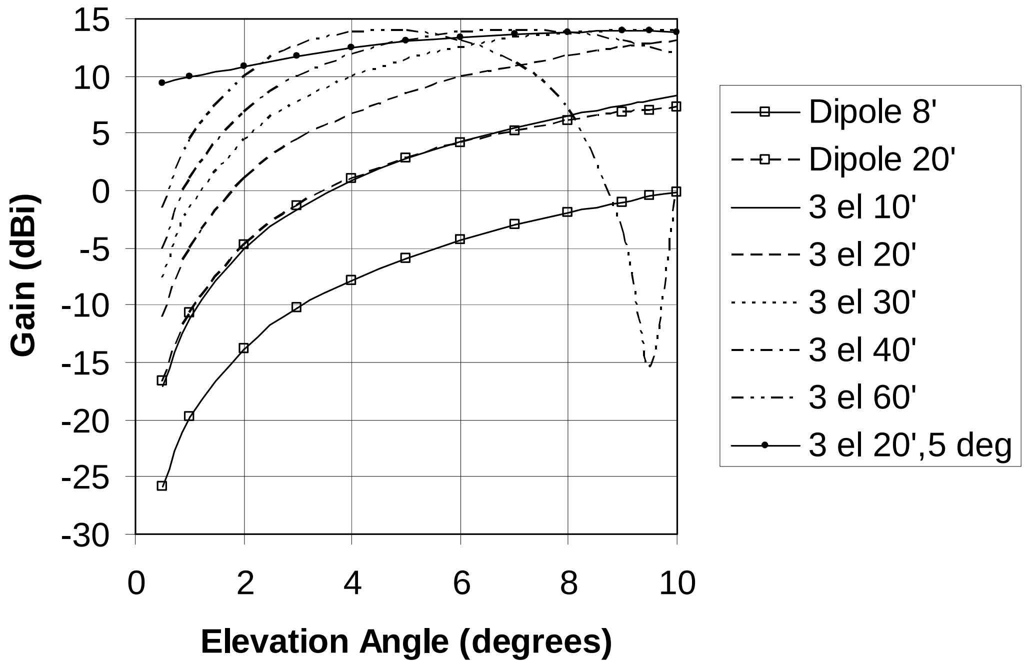

Figure 3: Elevation Patterns of Dipole and 3 Element Yagi

Conclusions

From the preceding calculations we can make the following observations.

(1) Most sporadic-E signals will have elevation angles under 10 degrees.
(2) Based just on distribution of land area and ignoring population density effects and the dependence of MUF on elevation angle, it seems that about half of Sporadic-E signals will have elevation angles under 3 degrees.

(3) Over flat level ground there is no antenna height that will give good gain at all elevation angles from 1-10 degrees. The optimum is probably about 50-60 feet, in order to get enhanced gain at low angles without losing too much in the first null (which falls at about 9.5 degrees at 60 feet). For larger stations, a choice between a high antenna and a low antenna may be useful. I have seen emails from a few serious VHF contesters attesting to the effectiveness of this arrangement (20'/40' and 20'/67' combinations were mentioned).
(4) A Rover operator must keep in mind that an antenna at 10 feet above ground will have a gain at low angles about 12 dB (2 S-units) below the same antenna at 40 feet. Half that difference can be made up if the antenna can be raised to 20 feet when the Rover is stationary.
(5) If sloping flat ground is available, a better pattern can be obtained for a low Rover antenna than for even a very high fixed station antenna. Compare the curves for the 20 foot high Yagi on 5 degree sloping ground with the 40 or 60 foot high flat ground cases, for example. At 1 degree elevation the 20 foot high Yagi is fully 20 dB better than the same antenna at the same height over flat ground.
(6) A dipole at 20 feet is as good as a 3 element Yagi at 10 feet, over flat ground.

Any of the antenna/height combinations used in this analysis are good enough to make single hop Sporadic-E contacts, since the signals are normally so loud. However, there are major differences in gain which can make a big difference in how long it takes to get through a contest pileup, or how well you can generate a pileup yourself.