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The 3YØX Peter I 160 Meter Beam Redux

Let's face it: Not many of us can erect a full-sized directive array for 160 meters, if for no other reason than the lack of a sufficiently tall support system. Nonetheless, in advance of the 2006 Peter I DXpedition, Bob Allphin, K4UEE, asked me to help design a 160 meter beam for 3YØX. He explained that Ralph, KØIR, had used a 3-element 160 meter beam *lying on the surface* during the 1994 DXpedition to Peter I, and he wanted to employ the same concept. Several weeks before the team had regrouped and was set to leave for the 2006 3YØ DXpedition I started looking into whether a 160-meter beam was feasible.

"The 3YØX Peter I Island 160 Meter Beam" in March 2009 *QST* recounts the tale of how this "beam without a tower" came to be and how it contributed to the DXpedition team's Top Band success from Peter I. This companion article will focus on concept and design considerations for such an antenna.

Antenna on Snow and Ice

To assure a successful design, the first thing we needed to know was the approximate conductivity (σ) and relative dielectric constant (εr) of the ice and snow in the glacier on Peter I. Our inability to find definitive data on polar ice cap electrical parameters dictated making a great deal of assumptions to come up with reasonable estimates.

I got in touch with my old friend, Pete Gaddie, W6XX, who had spent his career working for Stanford Research Institute (SRI) in the field of propagation. Pete had prior experience at measuring ground conductivity and dielectric constant. He did a search of the literature and other sources in an effort to determine the likely properties of the Peter I ice cap. He came up with figures that seemed to match the values I had determined would be needed if the antenna was to work.

While Pete was checking into the values for ice and snow, I had been modeling a 3-element antenna in free space and started modeling it above ground using *EZNEC*. For the antenna to be useful, it appeared that the relative dielectric constant could not exceed 2 and the ground conductivity could not exceed 100 μS/m (that's *micro*siemens, as opposed to the *milli*siemens we're used to seeing in the

conductivity tables).

In checking his sources, Pete further determined that there was a difference between Arctic and Antarctic ice — as well as for most of the ice between. It seemed, however, that the values for σ ranged in the low μS/m range — as low as 10 μS/m — while the value for εr was around 1.5 to 3.2. So, it looked like we might be in business. With εr and σ at these values the surface begins looking like an insulator.

It's said that in polar regions covered

System Installation and Performance

After arriving on Peter I, we got two stations on the air as soon as possible, putting up a Battle Creek Special for 160 meters. The pileups were as huge as you might imagine, although most-consistently received signal report was 559. I know what that means on Top Band: We were *not* very strong. It also was necessary to send the station's call sign several times. While we made lots of QSOs that first night, I was ready to try the wire beam Jim, Pete and I had been discussing for so long.

After analyzing the information I sent him for the 80 meter antenna, Jim e-mailed the proper dimensions for the three elements (see Figure 3) and the element spacing. He recommended mounting the elements as high above the ice and snow as possible.

Several team members and I braved severe weather to install the driven element, the reflector and the director on PVC pipes standing at about four feet above the surface. The SWR on the completed 3-element beam was a perfect 1:1.

We still got some 559 reports but now with some 589 and 599 reports thrown in, and we no longer had to repeat the station's call sign several times. The antenna was working and working well!

Several people told me after I returned home that we were so much stronger after erecting the beam that some operators thought it was a pirate station. One ham in Atlanta told me we were 20 dB over S9 on his meter. *Wow!*
— Bob Allphin, K4UEE

by an ice cap and snow, wire antenna elements laid directly on the surface will behave as if they were in free space. In fact, while the antenna may indeed work, it's unlikely to perform as if in free space. Its tuning and elevation pattern also will differ from its free space value due to the snow and ice cap beneath.

Polar icecaps over land typically consist of a top layer of snow that increases in density with age and depth, gradually transitioning into ice. The surface may vary from lightly to densely packed snow. In areas where it rains, there may be alternating layers of snow and ice. During warm or rainy periods the surface may even be slush.

The relative dielectric constant of lightly packed snow is about 1.2, and it increases with density. The εr of ice is about 3.2, while fresh water is about 78. The conductivity of pure snow and ice is very low, but if contaminated by salt spray or other pollutants the σ value may increase significantly.

A 160 or 80 meter Yagi built with small wire elements is inherently a narrowband device. For good performance, elements must be accurately tuned. The gain and pattern of antennas such as V beams, rhombics or extended double Zepps would be less affected by such detuning effects. Such antennas may be designed within certain limitations by using the *NEC2* or *NEC4* modeling engines. A basic limitation of these modeling programs is their assumption that the antenna will be installed in or over a homogeneous medium. That's obviously *not* the case here, as the εr almost certainly will vary with depth. Therefore, we'll estimate the medium's composite parameters.

Getting Above It All

Some experiments with *NEC4* indicated that element tuning errors caused by incorrect estimates of the medium's electrical parameters could be reduced considerably by slightly *elevating* the elements instead of laying them on or in the snow-ice medium. This is particularly true in situations where the surface may change from snow to slush. We used a *NEC4* wire sheath model to approximate the likely effect on a 160 meter antenna element in slush. The resonant frequency of a 160 meter dipole with 2 mm diameter wire surrounded by 5 mm of radial ice is reduced by 8.6 percent.
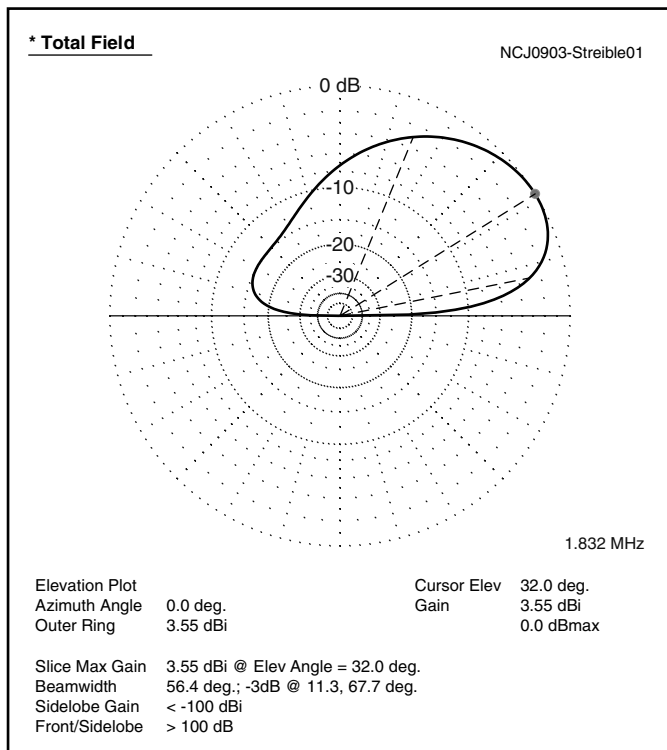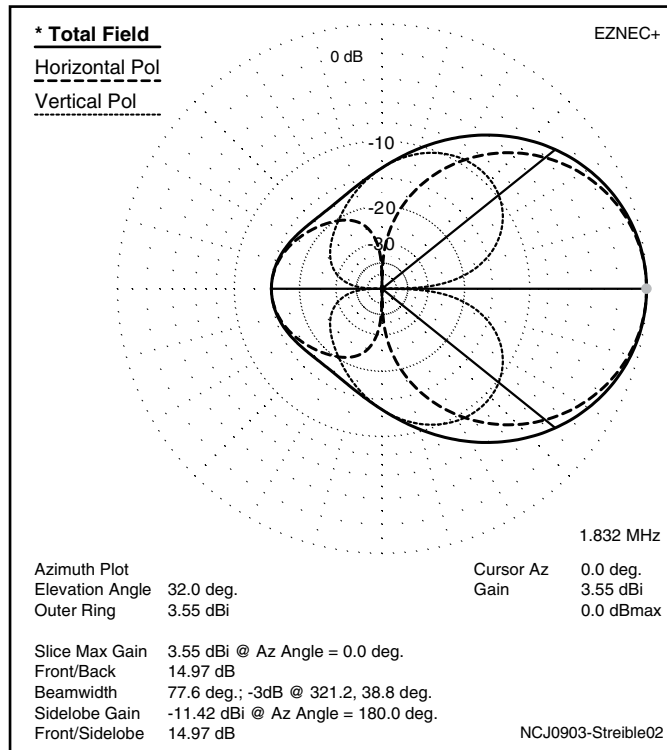
Figure 1 — Elevation pattern for the 160 meter beam
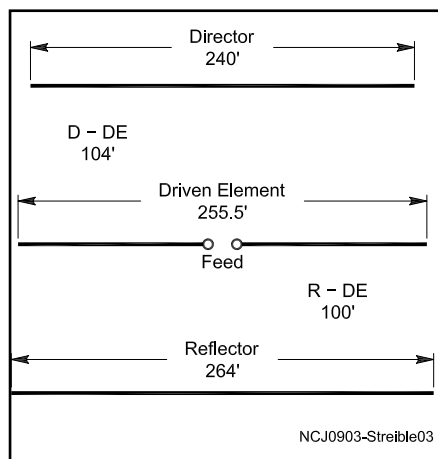

Figure 2 — Azimuth pattern for the 160 meter beam

Figure 3 — Element dimensions for the 160 meter beam

Figure 4 — K4UEE measures the director for the 160 meter beam.

If surrounded by a 5 mm radius of water, it drops by 12.6 percent. Clearly you don't want a wire antenna element lying in slush. The modeling indicated that a height of 10 feet or greater was desirable but that elevating the antenna just a few feet offered considerable advantage over surface mounting.

I ran several plots with different values and settled on a σ of 0.00001 S/m and an εr of 1.2. This indicated that at four feet above the ice the antenna would exhibit a gain of 3.55 dBi and a takeoff angle of 32° (see Figures 1 and 2). Since the conditions

in which the DXpedition team would be erecting the antenna were unknown, one criterion was to adjust the spacing and tuning to obtain a feed point impedance as close to 50 Ω as possible. This would obviate the necessity of having to do any matching on site in the anticipated cold and windy climate.

How did we decide on four feet? After discussions with Bob, we came up with an

idea that the team would carry along some stakes that were long enough to drive into the ice to support the antenna and at a height of about four feet. I believed this would offer just enough margin to achieve reasonable performance.

Aiming the Array

Since this is not an antenna you can rotate, we had to decide where to aim it.

To cover Europe and the most Amateur Radio-populated countries, it looked like about 40° would be the best bet. The beamwidth of this antenna would be approximately 80°, so it should cover the US, South America, Europe and part of North Africa. Unfortunately, this would be less favorable for Asia and Oceania.

With all the plots done, it looked like this antenna just might offer some advantage on 160 meters. *Let me be clear*: Had this operation been on a beach, where many such operations take place, this antenna, at best, would have been a good dummy load. Verticals like the Battle Creek Special would have cleaned its clock. This operation, however, was taking place on a glacier some 250 to 300 feet (or more) thick with rock beneath, and the team was set up about 600 to 700 feet above sea level and one-half mile back from the glacier's edge. As a result, the advantage of an initial reflection off salt water that most island operations enjoy was lacking here.

Attempted Ground Parameter Measurement

In principal ground parameters can be determined by measuring the impedance of a dipole at several heights and comparing these data with modeled predictions. George Hagan and others at SRI had pioneered this method in the 1960s. We gave Bob the dimensions of an 80 meter dipole and asked him to take some measurements of impedance vs height and to e-mail the results to us.

When they arrived, however, team members found themselves slogging around in ankle-deep slush. The measurements were made with the dipole on the surface as well as at heights of three feet and five feet. Initial results from these data were inconclusive, but they went ahead and installed the 160 meter antenna using the original estimated parameters. Interferences drawn from on-the-air reports suggest that this was a wise choice.

Later their measurements were further analyzed by throwing out the on-the-surface measurement because of its contamination by the wet slush. That analysis indicated the apparent εr was 1.5 to 1.8, and σ was about 5 μS/m.

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