Phase Centre Location Determination for Locatalite Antenna in the LocataNet System

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ABSTRACT
Commonly, distances measured in radiowave surveying are approximated to that between the geometrical centers of the transmitting and receiving antennas. However, for millimetre-level accuracy, as is possible using the LocataNet System, this approximation is unacceptable. The phase centers of both antennas are required as the reference points. A certain technique was implemented to find the variation of phase centre of the proposed Locatalite antennas with frequency. This paper presents the results of this variation.

KEYWORDS: Antenna, phase centre, Locatalite

INTRODUCTION
Given a radiating object, the point from which radiation may be said to emanate is called the Phase Center. This could vary with azimuth and elevation angle, and polarization of radiated wave at the point of observation. Geometrical centroids of most antennas are not their phase centers [1]. Now in LocataNet [4], a radio trilateration systems analogous to GPS, accuracy of less than a centimeter is required. Thus, error in referring to the geometrical center instead to the phase center will be significant. This paper will report an experiment intended to find phase center, at an order of millimeter, at various frequencies of operation.

Most methods in finding phase center involved measuring the phase pattern of the antenna under test (AUT). When the phase pattern is plotted with $Cos\phi$, where ϕ is azimuth angle, as its domain the slope of its linear portion is taken as proportional to the phase center distance from antenna's point of rotation to its phase center in [2]. While in [1] the radius of curvature in the equiphase polar plot is used to calculate the phase center. And in [3] phase center is solved by minimizing the error between the measured phase and model phase function.

In the following sections the method of finding phase center is discussed then the experimental setup for measuring phase pattern is described, and lastly the experimental results are shown and analyzed.

PHASE CENTER
Let θ be the elevation angle, ϕ the azimuth angle, $M(\theta,\phi)$ as the field magnitude, $P(\theta,\phi)$ as the phase, and **r** as the polarization direction. At far-field the received electric field is,

$$\mathbf{E} = M(\theta,\phi)\text{Exp}[jP(\theta,\phi)]\mathbf{r}$$

In some range of ϕ, with fixed θ, the phase could be expressed as **[2**],

(1) $$P(\phi) = ksCos(\phi) + \delta$$

where δ is some fixed phase shift, $k = 2\pi/\lambda$ is the wave number, λ is the wavelength, and s is the distance from the point of antenna rotation to the phase center in the θ plane. By differentiating Equation (1) with respect to $Cos(\phi)$, one obtains,

(2) $$s = \frac{dP(\phi)}{kdCos(\phi)}$$

This implies that s is proportional to the slope of $P(\phi)$ with respect to $Cos(\phi)$ as its domain.

Due to measurement error the differentiation will yield a strongly varying value of s with respect to ϕ. One way to circumvent this problem is to fit Equation (1) to the measured phase P_m through least square minimization, i.e.,

(3) $$min_{s,e} \{|P_m - P|^2\}$$

from which s could be known.

EXPERIMENT

The antenna under test is an Aerotek Antenna with model number AT2400-2W-RSMAM-008-00-05-L shown in Figure 1 colored White with the silver metal behind it as its holder. In the phase pattern measurement this is placed inside an anechoic chamber to prevent non-direct waves to be received from the transmitter *Tx*. Further, this is positioned at vertical polarization and is rotated about the vertical *z* axis at *C* which is the centroid of the antenna's back plate sandwiched between the antenna holder *Ah* and its back plate as illustrated in Figure 2. As the antenna is rotated the phase of the received signal, at $\theta = 90^o$ plane and a fixed distance to *C*, is logged together with the angle of observation ϕ with respect to bore sight yielding its phase pattern.

Figure 1: Antenna under test

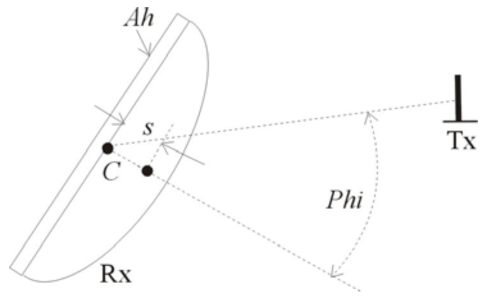

Figure 2: Experimental setup for Phase Centre determination

RESULTS AND ANALYSIS

The phase patterns were gathered for the AUT at frequencies of 2.41428, 2.42451, 2.43471, 2.44497, 2.4552, and 2.46543 GHz. A sample phase pattern with $Cos(\phi)$ as the domain is shown in Figure 3 for frequency of 2.41428 GHz. Notice the change of slope at -.65 (equivalent to ϕ of 130.54^o). As mentioned above the phase pattern slope is linearly related to the phase center distance *s*. Thus, in the succeeding analysis, calculated value of *s* only applies to a limited range of azimuth angles. As well, the randomness due to measurement error requires the application of minimization mentioned above.

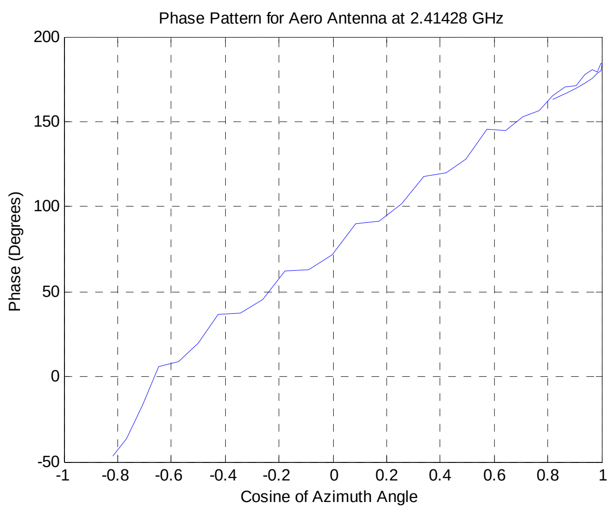

Figure 3: Phase pattern of Aero antenna at vertical polarization and frequency of 2.4143 GHz

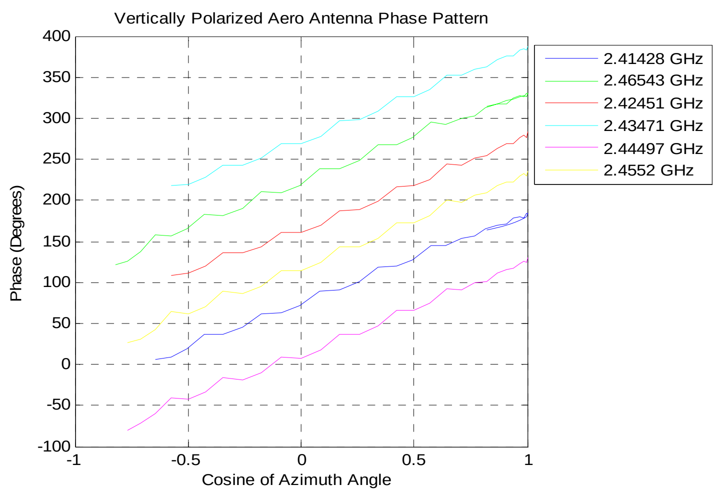

Figure 4: Phase patterns of AUT with vertical polarization

The phase patterns of AUT, at limited range of azimuth angles, for all frequencies considered are shown in Figure 4. It should be noted in these figures that graphs with phase angles greater than 360^o are lowered by 180^o. As shown, phase patterns slope and level varies with frequency, which is to be expected since behavior of most antennas varies with this parameter.

Applying Equations (1) and (3) to the phase patterns above yield the phase center distance *s* in Table 1.

Table 1: Phase center as a function of frequency

Frequency (GHz)	2.41428	2.42451	2.43471	2.44497	2.4552	2.46543
Aero Phase Center (mm)	3.2545	4.5336	4.0567	4.9135	5.2121	3.7674

Basing from Equation (2) the variation in phase pattern slope in Figure 4 with frequency will result to the phase center distance variation as well, which explains results in Table 1.

CONCLUDING REMARKS

This result showed that the phase center of the AUT is in the order of millimeter and varies with frequency in a nonlinear relationship. Further, it remains constant over a wide range of azimuth angles as evident in the constant slopes of their corresponding phase pattern.

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