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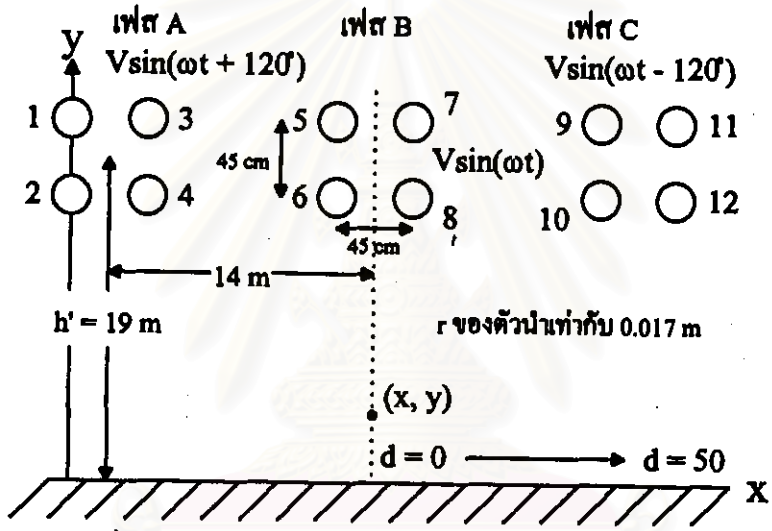
ภาคผนวก

ตัวอย่างการคำนวณ

1. ตัวอย่างการคำนวณค่าความเข้มสนามไฟฟ้าใต้สายส่งจ่ายพลังงานไฟฟ้า

ตัวอย่างการคำนวณค่าความเข้มสนามไฟฟ้าใต้สายส่งจ่ายพลังงานไฟฟ้าที่นำมาแสดงในที่นี้จะเป็นสายส่งระบบ 500 kV 3 เฟส วงจรเดี่ยว สายควบ 4 เส้น ของการไฟฟ้าฝ่ายผลิตแห่งประเทศไทย ส่งพลังงานไฟฟ้าจากสถานีไฟฟ้าแรงสูงแม่เมาะ3 จ.ลำปาง ลงมายังสถานีไฟฟ้าแรงสูงท่าตะโก จ.นครสวรรค์ ขณะจ่ายกระแสไฟฟ้าต่อเฟสประมาณ 500 A รูปที่ ก.1 แสดงลักษณะการติดตั้งและระยะต่างๆ ซึ่งต้องใช้ในการคำนวณ โดยความสูงที่แสดงในรูปเป็นความสูงต่ำสุดของสายส่งที่ตำแหน่งตกท้องช้าง



รูปที่ ก.1 ระบบสายส่ง 500 kV วงจรเดี่ยว พร้อมมิติต่างๆ

การคำนวณค่าความเข้มสนามไฟฟ้าสำหรับระบบสายส่งจ่ายพลังงานไฟฟ้าหลายเส้นนี้ จะต้องหาค่าประจุไฟฟ้าบนสายตัวนำแต่ละเส้นเสียก่อน โดยใช้สมการที่ 2.4 และ 2.5 เนื่องจากว่าแรงดันที่กระจายจากสายตัวนำแต่ละเส้นจะมีผลต่อสายตัวนำเส้นอื่น ๆ ทำให้ความหนาแน่นประจุไฟฟ้าบนสายตัวนำแต่ละเส้นมีค่าไม่เท่ากัน

แทนค่าต่างๆลงในสมการที่ 2.4 และ 2.5 เมื่อกำหนดให้จุดที่ต้องการพิจารณา (x, y) คือจุดที่อยู่ที่ผิวล่างของสายตัวนำแต่ละเส้น

$$V(x, y) = \frac{\rho}{2\pi\varepsilon_0} \ell n \left[\frac{(y + y')^2 + (x - x')^2}{(y - y')^2 + (x - x')^2} \right] = \rho Z$$

$$\rho_1 Z_{1,1} + \rho_2 Z_{1,2} + \bullet\ \bullet\ \bullet + \rho_n Z_{1,n} = V_1$$
$$\rho_1 Z_{2,1} + \rho_2 Z_{2,2} + \bullet\ \bullet\ \bullet + \rho_n Z_{2,n} = V_2$$
$$\bullet \quad \bullet \qquad \bullet \quad \bullet$$
$$\bullet \quad \bullet \qquad \bullet \quad \bullet$$
$$\bullet \quad \bullet \qquad \bullet \quad \bullet$$
$$\rho_1 Z_{m,1} + \rho_2 Z_{m,2} + \bullet\ \bullet\ \bullet + \rho_n Z_{m,n} = V_m$$

เมื่อ (x, y) คือ จุดที่ต้องการพิจารณา

(x', y') คือ ตำแหน่งที่ตั้งของสายตัวนำ

$Z_{m,n}$ คือ ผลของสายตัวนำ n บนสายตัวนำ m โดยที่ n เท่ากับ m

ρ_n คือ ความหนาแน่นประจุไฟฟ้าบนสายตัวนำ n

V_m คือ ค่าแรงดันไฟฟ้าซึ่งทราบค่าของสายตัวนำ m

$$\rho_1 Z_{1,1} = \frac{\rho_1}{2\pi\varepsilon_0} \ln\left[\frac{(19.208+19.225)^2 + (14.225-14.225)^2}{(19.208-19.225)^2 + (14.225-14.225)^2}\right] = \rho_1 2.777E+11$$

$$\rho_2 Z_{1,2} = \frac{\rho_2}{2\pi\varepsilon_0} \ln\left[\frac{(18.758+19.225)^2 + (14.225-14.225)^2}{(18.758-19.225)^2 + (14.225-14.225)^2}\right] = \rho_2 1.581E+11$$

$$\bullet \quad \bullet \quad \bullet \quad \bullet \quad \bullet \quad \bullet$$
$$\bullet \quad \bullet \quad \bullet \quad \bullet \quad \bullet \quad \bullet$$
$$\bullet \quad \bullet \quad \bullet \quad \bullet \quad \bullet \quad \bullet$$

$$\rho_{11} Z_{1,11} = \frac{\rho_{11}}{2\pi\varepsilon_0} \ln\left[\frac{(19.208+19.225)^2 + (-14.225-14.225)^2}{(19.208-19.225)^2 + (-14.225-14.225)^2}\right] = \rho_{11} 1.867E+10$$

$$\rho_{12} Z_{1,12} = \frac{\rho_{12}}{2\pi\varepsilon_0} \ln\left[\frac{(18.758+19.225)^2 + (-14.225-14.225)^2}{(18.758-19.225)^2 + (-14.225-14.225)^2}\right] = \rho_{12} 1.839E+10$$

$$\rho_1 Z_{2,1} = \frac{\rho_1}{2\pi\varepsilon_0} \ell n\left[\frac{(19.208+18.775)^2 + (14.225-14.225)^2}{(19.208-18.775)^2 + (14.225-14.225)^2}\right] = \rho_1 1.609E+11$$

$$\rho_2 Z_{2,2} = \frac{\rho_2}{2\pi\varepsilon_0} \ell n\left[\frac{(18.758+18.775)^2 + (14.225-14.225)^2}{(18.758-18.775)^2 + (14.225-14.225)^2}\right] = \rho_2 2.768E+11$$

$$\vdots \quad \vdots \quad \vdots \quad \vdots \quad \vdots \quad \vdots$$

$$\rho_{11} Z_{2,11} = \frac{\rho_{11}}{2\pi\varepsilon_0} \ell n\left[\frac{(19.208+18.775)^2 + (-14.225-14.225)^2}{(19.208-18.775)^2 + (-14.225-14.225)^2}\right] = \rho_{11} 1.839E+10$$

$$\rho_{12} Z_{2,12} = \frac{\rho_{12}}{2\pi\varepsilon_0} \ell n\left[\frac{(18.758+18.775)^2 + (-14.225-14.225)^2}{(18.758-18.775)^2 + (-14.225-14.225)^2}\right] = \rho_{12} 1.812E+10$$

$$\rho_1 Z_{3,1} = \frac{\rho_1}{2\pi\varepsilon_0} \ell n\left[\frac{(19.208+19.225)^2 + (14.225-13.775)^2}{(19.208-19.225)^2 + (14.225-13.775)^2}\right] = \rho_1 1.599E+11$$

$$\rho_2 Z_{3,2} = \frac{\rho_2}{2\pi\varepsilon_0} \ell n\left[\frac{(18.758+19.225)^2 + (14.225-13.775)^2}{(18.758-19.225)^2 + (14.225-13.775)^2}\right] = \rho_2 1.463E+11$$

$$\vdots \quad \vdots \quad \vdots \quad \vdots \quad \vdots \quad \vdots$$

$$\rho_{11} Z_{3,11} = \frac{\rho_{11}}{2\pi\varepsilon_0} \ell n\left[\frac{(19.208+19.225)^2 + (-14.225-13.775)^2}{(19.208-19.225)^2 + (-14.225-13.775)^2}\right] = \rho_{11} 1.904E+10$$

$$\rho_{12} Z_{3,12} = \frac{\rho_{12}}{2\pi\varepsilon_0} \ell n\left[\frac{(18.758+19.225)^2 + (-14.225-13.775)^2}{(18.758-19.225)^2 + (-14.225-13.775)^2}\right] = \rho_{12} 1.876E+10$$

$$\rho_1 Z_{4,1} = \frac{\rho_1}{2\pi\varepsilon_0} \ell n\left[\frac{(19.208+18.775)^2 + (14.225-13.775)^2}{(19.208-18.775)^2 + (14.225-13.775)^2}\right] = \rho_1 1.477E+11$$

$$\rho_2 Z_{4,2} = \frac{\rho_2}{2\pi\varepsilon_0} \ell n\left[\frac{(18.758+18.775)^2 + (14.225-13.775)^2}{(18.758-18.775)^2 + (14.225-13.775)^2}\right] = \rho_2 1.590E+11$$

$$\vdots \quad \vdots \quad \vdots \quad \vdots \quad \vdots \quad \vdots$$

$$\rho_{11} Z_{4,11} = \frac{\rho_{11}}{2\pi\varepsilon_0} \ell n\left[\frac{(19.208+18.775)^2 + (-14.225-13.775)^2}{(19.208-18.775)^2 + (-14.225-13.775)^2}\right] = \rho_{11} 1.876E+10$$

$$\rho_{12} Z_{4,12} = \frac{\rho_{12}}{2\pi\varepsilon_0} \ell n\left[\frac{(18.758+18.775)^2 + (-14.225-13.775)^2}{(18.758-18.775)^2 + (-14.225-13.775)^2}\right] = \rho_{12} 1.849E+10$$

$$\rho_1 Z_{5,1} = \frac{\rho_1}{2\pi\varepsilon_0} \ell n\left[\frac{(19.208+19.225)^2 + (14.225-0.225)^2}{(19.208-19.225)^2 + (14.225-0.225)^2}\right] = \rho_1 3.855E+10$$

$$\rho_2 Z_{5,2} = \frac{\rho_2}{2\pi\varepsilon_0} \ell n\left[\frac{(18.758+19.225)^2 + (14.225-0.225)^2}{(18.758-19.225)^2 + (14.225-0.225)^2}\right] = \rho_2 3.815E+10$$

$$\vdots \quad \vdots \quad \vdots \quad \vdots \quad \vdots \quad \vdots$$

$$\rho_{11} Z_{5,11} = \frac{\rho_{11}}{2\pi\varepsilon_0} \ell n\left[\frac{(19.208+19.225)^2 + (-14.225-0.225)^2}{(19.208-19.225)^2 + (-14.225-0.225)^2}\right] = \rho_{11} 3.754E+10$$

$$\rho_{12} Z_{5,12} = \frac{\rho_{12}}{2\pi\varepsilon_0} \ell n\left[\frac{(18.758+19.225)^2 + (-14.225-0.225)^2}{(18.758-19.225)^2 + (-14.225-0.225)^2}\right] = \rho_{12} 3.716E+10$$

$$\rho_1 Z_{6,1} = \frac{\rho_1}{2\pi\varepsilon_0} \ell n\left[\frac{(19.208+18.775)^2 + (14.225-0.225)^2}{(19.208-18.775)^2 + (14.225-0.225)^2}\right] = \rho_1 3.815E+10$$

$$\rho_2 Z_{6,2} = \frac{\rho_2}{2\pi\varepsilon_0} \ell n\left[\frac{(18.758+18.775)^2 + (14.225-0.225)^2}{(18.758-18.775)^2 + (14.225-0.225)^2}\right] = \rho_2 3.780E+10$$

$$\vdots \quad \vdots \quad \vdots \quad \vdots \quad \vdots \quad \vdots$$

$$\rho_{11} Z_{6,11} = \frac{\rho_{11}}{2\pi\varepsilon_0} \ell n\left[\frac{(19.208+18.775)^2 + (-14.225-0.225)^2}{(19.208-18.775)^2 + (-14.225-0.225)^2}\right] = \rho_{11} 3.716E+10$$

$$\rho_{12} Z_{6,12} = \frac{\rho_{12}}{2\pi\varepsilon_0} \ell n\left[\frac{(18.758+18.775)^2 + (-14.225-0.225)^2}{(18.758-18.775)^2 + (-14.225-0.225)^2}\right] = \rho_{12} 3.680E+10$$

$$\rho_1 Z_{7,1} = \frac{\rho_1}{2\pi\varepsilon_0} \ell n\left[\frac{(19.208+19.225)^2 + (14.225+0.225)^2}{(19.208-19.225)^2 + (14.225+0.225)^2}\right] = \rho_1 3.754E+10$$

$$\rho_2 Z_{7,2} = \frac{\rho_2}{2\pi\varepsilon_0} \ell n\left[\frac{(18.758+19.225)^2 + (14.225+0.225)^2}{(18.758-19.225)^2 + (14.225+0.225)^2}\right] = \rho_2 3.716E+10$$

$$\vdots \quad \vdots \quad \vdots \quad \vdots \quad \vdots \quad \vdots$$

$$\rho_{11} Z_{7,11} = \frac{\rho_{11}}{2\pi\varepsilon_0} \ell n\left[\frac{(19.208+19.225)^2 + (-14.225+0.225)^2}{(19.208-19.225)^2 + (-14.225+0.225)^2}\right] = \rho_{11} 3.855E+10$$

$$\rho_{12} Z_{7,12} = \frac{\rho_{12}}{2\pi\varepsilon_0} \ell n\left[\frac{(18.758+19.225)^2 + (-14.225+0.225)^2}{(18.758-19.225)^2 + (-14.225+0.225)^2}\right] = \rho_{12} 3.815E+10$$

$$\rho_1 Z_{8,1} = \frac{\rho_1}{2\pi\varepsilon_0} \ln\left[\frac{(19.208+18.775)^2 + (14.225+0.225)^2}{(19.208-18.775)^2 + (14.225+0.225)^2}\right] = \rho_1 3.716E+10$$

$$\rho_2 Z_{8,2} = \frac{\rho_2}{2\pi\varepsilon_0} \ln\left[\frac{(18.758+18.775)^2 + (14.225+0.225)^2}{(18.758-18.775)^2 + (14.225+0.225)^2}\right] = \rho_2 3.680E+10$$

$$\vdots \quad \vdots \quad \vdots \quad \vdots \quad \vdots \quad \vdots$$

$$\rho_{11} Z_{8,11} = \frac{\rho_{11}}{2\pi\varepsilon_0} \ln\left[\frac{(19.208+18.775)^2 + (-14.225+0.225)^2}{(19.208-18.775)^2 + (-14.225+0.225)^2}\right] = \rho_{11} 3.815E+10$$

$$\rho_{12} Z_{8,12} = \frac{\rho_{12}}{2\pi\varepsilon_0} \ln\left[\frac{(18.758+18.775)^2 + (-14.225+0.225)^2}{(18.758-18.775)^2 + (-14.225+0.225)^2}\right] = \rho_{12} 3.780E+10$$

$$\rho_1 Z_{9,1} = \frac{\rho_1}{2\pi\varepsilon_0} \ln\left[\frac{(19.208+19.225)^2 + (14.225+13.775)^2}{(19.208-19.225)^2 + (14.225+13.775)^2}\right] = \rho_1 1.904E+10$$

$$\rho_2 Z_{9,2} = \frac{\rho_2}{2\pi\varepsilon_0} \ln\left[\frac{(18.758+19.225)^2 + (14.225+13.775)^2}{(18.758-19.225)^2 + (14.225+13.775)^2}\right] = \rho_2 1.876E+10$$

$$\vdots \quad \vdots \quad \vdots \quad \vdots \quad \vdots \quad \vdots$$

$$\rho_{11} Z_{9,11} = \frac{\rho_{11}}{2\pi\varepsilon_0} \ln\left[\frac{(19.208+19.225)^2 + (-14.225+13.775)^2}{(19.208-19.225)^2 + (-14.225+13.775)^2}\right] = \rho_{11} 1.599E+11$$

$$\rho_{12} Z_{9,12} = \frac{\rho_{12}}{2\pi\varepsilon_0} \ln\left[\frac{(18.758+19.225)^2 + (-14.225+13.775)^2}{(18.758-19.225)^2 + (-14.225+13.775)^2}\right] = \rho_{12} 1.463E+11$$

$$\rho_1 Z_{10,1} = \frac{\rho_1}{2\pi\varepsilon_0} \ln\left[\frac{(19.208+18.775)^2 + (14.225+13.775)^2}{(19.208-18.775)^2 + (14.225+13.775)^2}\right] = \rho_1 1.876E+10$$

$$\rho_2 Z_{10,2} = \frac{\rho_2}{2\pi\varepsilon_0} \ln\left[\frac{(18.758+18.775)^2 + (14.225+13.775)^2}{(18.758-18.775)^2 + (14.225+13.775)^2}\right] = \rho_2 1.849E+10$$

$$\vdots \quad \vdots \quad \vdots \quad \vdots \quad \vdots \quad \vdots$$

$$\rho_{11} Z_{10,11} = \frac{\rho_{11}}{2\pi\varepsilon_0} \ln\left[\frac{(19.208+18.775)^2 + (-14.225+13.775)^2}{(19.208-18.775)^2 + (-14.225+13.775)^2}\right] = \rho_{11} 1.477E+11$$

$$\rho_{12} Z_{10,12} = \frac{\rho_{12}}{2\pi\varepsilon_0} \ln\left[\frac{(18.758+18.775)^2 + (-14.225+13.775)^2}{(18.758-18.775)^2 + (-14.225+13.775)^2}\right] = \rho_{12} 1.590E+11$$

$$\rho_1 Z_{11,1} = \frac{\rho_1}{2\pi\varepsilon_0} \ell n\left[\frac{(19.208+19.225)^2 + (14.225+14.225)^2}{(19.208-19.225)^2 + (14.225+14.225)^2}\right] = \rho_1 1.867E+10$$

$$\rho_2 Z_{11,2} = \frac{\rho_2}{2\pi\varepsilon_0} \ell n\left[\frac{(18.758+19.225)^2 + (14.225+14.225)^2}{(18.758-19.225)^2 + (14.225+14.225)^2}\right] = \rho_2 1.839E+10$$

$$\vdots \quad \vdots \quad \vdots \quad \vdots \quad \vdots \quad \vdots$$

$$\rho_{11} Z_{11,11} = \frac{\rho_{11}}{2\pi\varepsilon_0} \ell n\left[\frac{(19.208+19.225)^2 + (-14.225+14.225)^2}{(19.208-19.225)^2 + (-14.225+14.225)^2}\right] = \rho_{11} 2.777E+11$$

$$\rho_{12} Z_{11,12} = \frac{\rho_{12}}{2\pi\varepsilon_0} \ell n\left[\frac{(18.758+19.225)^2 + (-14.225+14.225)^2}{(18.758-19.225)^2 + (-14.225+14.225)^2}\right] = \rho_{12} 1.581E+11$$

$$\rho_1 Z_{12,1} = \frac{\rho_1}{2\pi\varepsilon_0} \ell n\left[\frac{(19.208+18.775)^2 + (14.225+14.225)^2}{(19.208-18.775)^2 + (14.225+14.225)^2}\right] = \rho_1 1.839E+10$$

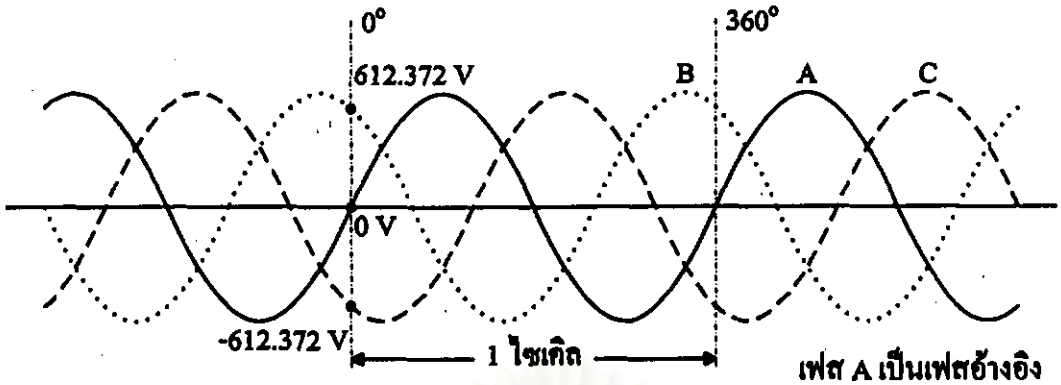
$$\rho_2 Z_{12,2} = \frac{\rho_2}{2\pi\varepsilon_0} \ell n\left[\frac{(18.758+18.775)^2 + (14.225+14.225)^2}{(18.758-18.775)^2 + (14.225+14.225)^2}\right] = \rho_2 1.812E+10$$

$$\vdots \quad \vdots \quad \vdots \quad \vdots \quad \vdots \quad \vdots$$

$$\rho_{11} Z_{12,11} = \frac{\rho_{11}}{2\pi\varepsilon_0} \ell n\left[\frac{(19.208+18.775)^2 + (-14.225+14.225)^2}{(19.208-18.775)^2 + (-14.225+14.225)^2}\right] = \rho_{11} 1.609E+11$$

$$\rho_{12} Z_{12,12} = \frac{\rho_{12}}{2\pi\varepsilon_0} \ell n\left[\frac{(18.758+18.775)^2 + (-14.225+14.225)^2}{(18.758-18.775)^2 + (-14.225+14.225)^2}\right] = \rho_{12} 2.768E+11$$

และเมื่อคิดผลของรูปคลื่นแรงดันที่มีมุมเฟสนำและตามกันอยู่ 120° ดังรูปที่ ก.2 จะต้องแทนค่าแรงดันด้วยค่าจริงของแรงดันในตำแหน่งมุมเฟสที่พิจารณา จากรูป ณ ตำแหน่ง 0° แรงดันที่เฟส A มีค่า 0 V ประกอบด้วยสายตัวนำเส้นที่ 1-4 เฟส B มีค่า 612.372 V ประกอบด้วยสายตัวนำเส้นที่ 5-8 และเฟส C มีค่า -612.372 V ประกอบด้วยสายตัวนำเส้นที่ 9-12



รูปที่ ก.2 รูปคลื่นแรงดันที่มีมุมเฟสนำและตามกันอยู่ 120°

เมื่อแทนค่าทั้งหมดลงไปในสมการที่ 2.6 จะได้

$$\begin{bmatrix}\rho_1\\ \rho_2\\ \rho_3\\ \rho_4\\ \rho_5\\ \rho_6\\ \rho_7\\ \rho_8\\ \rho_9\\ \rho_{10}\\ \rho_{11}\\ \rho_{12}\end{bmatrix}^T \begin{bmatrix} 27.77 & 16.09 & 15.99 & 14.77 & 3.855 & 3.815 & 3.754 & 3.716 & 1.904 & 1.876 & 1.867 & 1.839\\ 15.81 & 27.68 & 14.63 & 15.90 & 3.815 & 3.780 & 3.716 & 3.680 & 1.876 & 1.849 & 1.839 & 1.812\\ 15.99 & 14.77 & 27.77 & 16.09 & 3.959 & 3.919 & 3.855 & 3.815 & 1.942 & 1.914 & 1.904 & 1.876\\ 14.53 & 15.90 & 15.81 & 27.68 & 3.919 & 3.883 & 3.815 & 3.780 & 1.914 & 1.886 & 1.876 & 1.849\\ 3.855 & 3.815 & 3.959 & 3.919 & 27.77 & 16.09 & 15.99 & 14.77 & 3.855 & 3.815 & 3.754 & 3.716\\ 3.815 & 3.780 & 3.919 & 3.883 & 15.81 & 27.68 & 14.63 & 15.90 & 3.815 & 3.780 & 3.716 & 3.680\\ 3.754 & 3.716 & 3.855 & 3.815 & 15.99 & 14.77 & 27.77 & 16.09 & 3.959 & 3.919 & 3.855 & 3.815\\ 3.716 & 3.680 & 3.815 & 3.780 & 14.63 & 15.90 & 15.81 & 27.68 & 3.919 & 3.883 & 3.815 & 3.780\\ 1.904 & 1.876 & 1.942 & 1.914 & 3.855 & 3.815 & 3.959 & 3.919 & 27.77 & 16.09 & 15.99 & 14.77\\ 1.876 & 1.849 & 1.914 & 1.886 & 3.815 & 3.780 & 3.919 & 3.883 & 15.81 & 27.68 & 14.63 & 15.90\\ 1.867 & 1.839 & 1.904 & 1.876 & 3.754 & 3.716 & 3.855 & 3.815 & 15.99 & 14.77 & 27.77 & 16.09\\ 1.839 & 1.812 & 1.876 & 1.849 & 3.716 & 3.680 & 3.815 & 3.780 & 14.63 & 15.90 & 15.81 & 27.68 \end{bmatrix} \times 10^{10} = \begin{bmatrix} 0\\ 0\\ 0\\ 0\\ 612.372\\ 612.372\\ 612.372\\ 612.372\\ -612.372\\ -612.372\\ -612.372\\ -612.372 \end{bmatrix}^T$$

สามารถแก้สมการหาค่าประจุไฟฟ้าบนสายตัวนำแต่ละเส้นได้

$$\begin{bmatrix}\rho_1\\ \rho_2\\ \rho_3\\ \rho_4\\ \rho_5\\ \rho_6\\ \rho_7\\ \rho_8\\ \rho_9\\ \rho_{10}\\ \rho_{11}\\ \rho_{12}\end{bmatrix} = \begin{bmatrix} -1.02E\text{-}10\\ -1.04E\text{-}10\\ -1.23E\text{-}10\\ -1.25E\text{-}10\\ 1.027E\text{-}9\\ 1.062E\text{-}9\\ 1.055E\text{-}9\\ 1.091E\text{-}9\\ -1.028E\text{-}9\\ -1.064E\text{-}9\\ -9.96E\text{-}10\\ -1.032E\text{-}9 \end{bmatrix}$$

นำค่าประจุไฟฟ้าที่ได้ไปแทนค่าในสมการที่ 2.3 ข. หาค่าความเข้มสนามไฟฟ้าที่จุด (x, y) ใดๆ โดยในที่นี้จะแสดงการหาค่าความเข้มสนามไฟฟ้าที่จุด (0,1) ได้ค่าความเข้มสนามไฟฟ้าจากสายตัวนำแต่ละเส้นดังนี้

$$\bar{E}_1(0,1) = \frac{1.02E\text{-}10}{4\pi\varepsilon_0}\left[\frac{2(1+19.225)\bar{a}_y + 2(0-14.225)\bar{a}_x}{(1+19.225)^2 + (0-14.225)^2} - \frac{2(1-19.225)\bar{a}_y + 2(0-14.225)\bar{a}_x}{(1-19.225)^2 + (0-14.225)^2}\right]$$

$$= 0.12317\bar{a}_y + 6.1374E\text{-}3\,\bar{a}_x$$

$$\bar{E}_2(0,1) = \frac{1.04E\text{-}10}{4\pi\varepsilon_0}\left[\frac{2(1+18.775)\bar{a}_y + 2(0-14.225)\bar{a}_x}{(1+18.775)^2 + (0-14.225)^2} - \frac{2(1-18.775)\bar{a}_y + 2(0-14.225)\bar{a}_x}{(1-18.775)^2 + (0-14.225)^2}\right]$$

$$= 0.12641\bar{a}_y + 6.49345E\text{-}3\,\bar{a}_x$$

$$\bar{E}_3(0,1) = \frac{1.23E\text{-}10}{4\pi\varepsilon_0}\left[\frac{2(1+19.225)\bar{a}_y + 2(0-13.775)\bar{a}_x}{(1+19.225)^2 + (0-13.775)^2} - \frac{2(1-19.225)\bar{a}_y + 2(0-13.775)\bar{a}_x}{(1-19.225)^2 + (0-13.775)^2}\right]$$

$$= 0.15188\bar{a}_y + 7.49433E\text{-}3\,\bar{a}_x$$

$$\bar{E}_4(0,1) = \frac{1.25E\text{-}10}{4\pi\varepsilon_0}\left[\frac{2(1+18.775)\bar{a}_y + 2(0-13.775)\bar{a}_x}{(1+18.775)^2 + (0-13.775)^2} - \frac{2(1-18.775)\bar{a}_y + 2(0-13.775)\bar{a}_x}{(1-18.775)^2 + (0-13.775)^2}\right]$$

$$= 0.15548\bar{a}_y + 7.91408E\text{-}3\,\bar{a}_x$$

$$\bar{E}_5(0,1) = \frac{-1.027E\text{-}9}{4\pi\varepsilon_0}\left[\frac{2(1+19.225)\bar{a}_y + 2(0-0.225)\bar{a}_x}{(1+19.225)^2 + (0-0.225)^2} - \frac{2(1-19.225)\bar{a}_y + 2(0-0.225)\bar{a}_x}{(1-19.225)^2 + (0-0.225)^2}\right]$$

$$= -1.92546\bar{a}_y - 2.35032E\text{-}3\,\bar{a}_x$$

$$\bar{E}_6(0,1) = \frac{-1.062E\text{-}9}{4\pi\varepsilon_0}\left[\frac{2(1+18.775)\bar{a}_y + 2(0-0.225)\bar{a}_x}{(1+18.775)^2 + (0-0.225)^2} - \frac{2(1-18.775)\bar{a}_y + 2(0-0.225)\bar{a}_x}{(1-18.775)^2 + (0-0.225)^2}\right]$$

$$= -2.039\bar{a}_y - 2.61006E\text{-}3\,\bar{a}_x$$

$$\bar{E}_7(0,1) = \frac{-1.055E\text{-}9}{4\pi\varepsilon_0}\left[\frac{2(1+19.225)\bar{a}_y + 2(0+0.225)\bar{a}_x}{(1+19.225)^2 + (0+0.225)^2} - \frac{2(1-19.225)\bar{a}_y + 2(0+0.225)\bar{a}_x}{(1-19.225)^2 + (0+0.225)^2}\right]$$

$$= -1.97796\bar{a}_y + 2.4144E\text{-}3\,\bar{a}_x$$

$$\bar{E}_8(0,1) = \frac{-1.091E\text{-}9}{4\pi\varepsilon_0}\left[\frac{2(1+18.775)\bar{a}_y + 2(0+0.225)\bar{a}_x}{(1+18.775)^2 + (0+0.225)^2} - \frac{2(1-18.775)\bar{a}_y + 2(0+0.225)\bar{a}_x}{(1-18.775)^2 + (0+0.225)^2}\right]$$

$$= -2.09468\bar{a}_y + 2.68133E\text{-}3\,\bar{a}_x$$

$$\bar{E}_9(0,1) = \frac{1.028E\text{-}9}{4\pi\varepsilon_0}\left[\frac{2(1+19.225)\bar{a}_y + 2(0+13.775)\bar{a}_x}{(1+19.225)^2 + (0+13.775)^2} - \frac{2(1-19.225)\bar{a}_y + 2(0+13.775)\bar{a}_x}{(1-19.225)^2 + (0+13.775)^2}\right]$$

$$= 1.2694\bar{a}_y - 6.26356E\text{-}2\,\bar{a}_x$$

$$\bar{E}_{10}(0,1) = \frac{1.064E\text{-}9}{4\pi\varepsilon_0}\left[\frac{2(1+18.775)\bar{a}_y + 2(0+13.775)\bar{a}_x}{(1+18.775)^2 + (0+13.775)^2} - \frac{2(1-18.775)\bar{a}_y + 2(0+13.775)\bar{a}_x}{(1-18.775)^2 + (0+13.775)^2}\right]$$

$$= 1.32342\bar{a}_y - 6.73646E\text{-}2\,\bar{a}_x$$

$$\bar{E}_{11}(0,1) = \frac{9.96E\text{-}10}{4\pi\varepsilon_0}\left[\frac{2(1+19.225)\bar{a}_y + 2(0+14.225)\bar{a}_x}{(1+19.225)^2 + (0+14.225)^2} - \frac{2(1-19.225)\bar{a}_y + 2(0+14.225)\bar{a}_x}{(1-19.225)^2 + (0+14.225)^2}\right]$$

$$= 1.20267\bar{a}_y - 5.993E\text{-}2\,\bar{a}_x$$

$$\bar{E}_{12}(0,1) = \frac{1.032E\text{-}9}{4\pi\varepsilon_0}\left[\frac{2(1+18.775)\bar{a}_y + 2(0+14.225)\bar{a}_x}{(1+18.775)^2 + (0+14.225)^2} - \frac{2(1-18.775)\bar{a}_y + 2(0+14.225)\bar{a}_x}{(1-18.775)^2 + (0+14.225)^2}\right]$$

$$= 1.2544\bar{a}_y - 6.4435E\text{-}2\,\bar{a}_x$$

รวม $\bar{E}_1$ ถึง $\bar{E}_{12}$ ได้ $\bar{E}(0,1) = -2.43027\,\bar{a}_y - 0.22619\,\bar{a}_x$ kV/m

$= 2.443$ kV/m

ค่าความเข้มสนามไฟฟ้า $\bar{E}(0,1)$ ที่ได้นี้เป็นเพียงค่าที่จุดๆเดียวของตำแหน่งมุมเฟสหนึ่งบนรูปคลื่นแรงดัน ซึ่งการจะหาค่า $\bar{E}_{rms}(0,1)$ ทั้งหมด จะต้องหาค่า $\bar{E}(0,1)$ ที่ตำแหน่งมุมเฟสอื่นๆบนรูปคลื่นแรงดันจนครบ 1 ไซเคิลของรูปคลื่นแรงดัน ความถูกต้องของค่าความเข้มสนามไฟฟ้าที่ได้จะขึ้นอยู่กับความถี่ของการแบ่งมุมเฟสบนรูปคลื่นแรงดันด้วย ในที่นี้ได้แบ่งรูปคลื่นแรงดันออกทีละ 5° ได้ค่าแรงดันที่ตำแหน่งมุมเฟสต่างๆ ดังแสดงในตารางที่ ก.1 ดังนั้นใน 1 ไซเคิลจะแบ่งได้ 72 จุด นั่นหมายความว่าการคำนวณ $\bar{E}_{rms}(x,y)$ แต่ละจุด ต้องคำนวณทั้งหมด 72 ครั้ง และนำผลที่ได้มาคำนวณหาค่า rms จากการคำนวณได้ผลดังแสดงในตารางที่ ก.2 โดยในระบบสายส่งหนึ่งๆ จะได้เมตริกซ์ Z แบบเดียวเท่านั้น นั่นคือในการหาค่าความเข้มสนามไฟฟ้าที่ตำแหน่ง (x, y) อื่นๆ สามารถใช้เมตริกซ์ Z ที่หาได้ข้างต้นในการคำนวณหาค่าประจุไฟฟ้าบนสายตัวนำแต่ละเส้น และแทนค่าเพื่อหาค่าความเข้มสนามไฟฟ้า

ตารางที่ ก.1 ค่าแรงดันจริงที่ใช้คำนวณของระบบ 500 kV

มุม \ เฟส	A	B	C
0	0.000	612.372	-612.372
5	61.628	579.228	-640.856
10	122.788	541.675	-664.463
15	183.013	500.000	-683.013
20	241.845	454.519	-696.364
25	298.836	405.580	-704.416
30	353.553	353.553	-707.107
35	405.580	298.836	-704.416
40	454.519	241.845	-696.364
45	500.000	183.013	-683.013
50	541.675	122.788	-664.463
55	579.228	61.628	-640.856
60	612.372	0.000	-612.372
65	640.856	-61.628	-579.228
70	664.463	-122.788	-541.675
75	683.013	-183.013	-500.000
80	696.364	-241.845	-454.519
85	704.416	-298.836	-405.580
90	707.107	-353.553	-353.553
95	704.416	-405.580	-298.836
100	696.364	-454.519	-241.845
105	683.013	-500.000	-183.013
110	664.463	-541.675	-122.788
115	640.856	-579.228	-61.628
120	612.372	-612.372	0.000
125	579.228	-640.856	61.628
130	541.675	-664.463	122.788
135	500.000	-683.013	183.013
140	454.519	-696.364	241.845
145	405.580	-704.416	298.836
150	353.553	-707.107	353.553
155	298.836	-704.416	405.580
160	241.845	-696.364	454.519
165	183.013	-683.013	500.000
170	122.788	-664.463	541.675
175	61.628	-640.856	579.228

มุม \ เฟส	A	B	C
180	0.000	-612.372	612.372
185	-61.628	-579.228	640.856
190	-122.788	-541.675	664.463
195	-183.013	-500.000	683.013
200	-241.845	-454.519	696.364
205	-298.836	-405.580	704.416
210	-353.553	-353.553	707.107
215	-405.580	-298.836	704.416
220	-454.519	-241.845	696.364
225	-500.000	-183.013	683.013
230	-541.675	-122.788	664.463
235	-579.228	-61.628	640.856
240	-612.372	0.000	612.372
245	-640.856	61.628	579.228
250	-664.463	122.788	541.675
255	-683.013	183.013	500.000
260	-696.364	241.845	454.519
265	-704.416	298.836	405.580
270	-707.107	353.553	353.553
275	-704.416	405.580	298.836
280	-696.364	454.519	241.845
285	-683.013	500.000	183.013
290	-664.463	541.675	122.788
295	-640.856	579.228	61.628
300	-612.372	612.372	0.000
305	-579.228	640.856	-61.628
310	-541.675	664.463	-122.788
315	-500.000	683.013	-183.013
320	-454.519	696.364	-241.845
325	-405.580	704.416	-298.836
330	-353.553	707.107	-353.553
335	-298.836	704.416	-405.580
340	-241.845	696.364	-454.519
345	-183.013	683.013	-500.000
350	-122.788	664.463	-541.675
355	-61.628	640.856	-579.228

ตารางที่ ก.2 ผลการคำนวณค่าความเข้มสนามไฟฟ้าใต้สายส่ง 500 kV วงจรเดี่ยว

เฟส \ ระยะ (m)	0	1	2	3	4	5	6	7
0, 180	2.443	2.197	1.904	1.569	1.205	0.833	0.523	0.495
5, 185	2.314	2.038	1.718	1.363	0.989	0.637	0.465	0.674
10, 190	2.171	1.868	1.526	1.156	0.784	0.502	0.557	0.907
15, 195	2.014	1.686	1.326	0.949	0.606	0.483	0.741	1.156
20, 200	1.842	1.493	1.121	0.752	0.491	0.591	0.964	1.409
25, 205	1.653	1.287	0.911	0.579	0.492	0.778	1.203	1.662
30, 210	1.459	1.083	0.718	0.478	0.609	0.991	1.439	1.902
35, 215	1.258	0.880	0.556	0.494	0.790	1.213	1.670	2.130
40, 220	1.053	0.690	0.466	0.616	0.995	1.435	1.891	2.343
45, 225	0.849	0.533	0.495	0.797	1.211	1.655	2.103	2.544
50, 230	0.662	0.456	0.624	0.998	1.424	1.863	2.298	2.722
55, 235	0.514	0.499	0.804	1.207	1.632	2.059	2.478	2.881
60, 240	0.453	0.637	1.005	1.415	1.831	2.242	2.640	3.019
65, 245	0.512	0.821	1.212	1.617	2.019	2.409	2.783	3.135
70, 250	0.658	1.022	1.416	1.810	2.193	2.559	2.905	3.227
75, 255	0.845	1.227	1.615	1.992	2.351	2.690	3.006	3.296
80, 260	1.048	1.432	1.806	2.162	2.495	2.803	3.086	3.341
85, 265	1.253	1.627	1.983	2.314	2.618	2.894	3.141	3.360
90, 270	1.455	1.814	2.148	2.451	2.724	2.965	3.174	3.354
95, 275	1.649	1.988	2.296	2.569	2.807	3.010	3.181	3.321
100, 280	1.838	2.155	2.434	2.674	2.876	3.041	3.171	3.270
105, 285	2.010	2.300	2.548	2.753	2.917	3.042	3.131	3.187
110, 290	2.168	2.428	2.643	2.812	2.937	3.021	3.068	3.082
115, 295	2.311	2.539	2.719	2.850	2.935	2.977	2.981	2.953
120, 300	2.440	2.636	2.779	2.871	2.915	2.915	2.877	2.806
125, 305	2.549	2.709	2.815	2.867	2.870	2.829	2.748	2.636
130, 310	2.641	2.765	2.832	2.844	2.807	2.723	2.602	2.449
135, 315	2.714	2.800	2.828	2.801	2.722	2.598	2.436	2.244
140, 320	2.767	2.814	2.803	2.735	2.616	2.453	2.252	2.022
145, 325	2.795	2.804	2.753	2.647	2.489	2.287	2.049	1.784
150, 330	2.804	2.775	2.686	2.541	2.346	2.108	1.835	1.539
155, 335	2.795	2.727	2.600	2.418	2.188	1.916	1.612	1.288
160, 340	2.767	2.661	2.498	2.280	2.016	1.713	1.382	1.037
165, 345	2.716	2.573	2.373	2.122	1.827	1.497	1.144	0.790
170, 350	2.643	2.464	2.231	1.949	1.626	1.274	0.909	0.576
175, 355	2.552	2.338	2.074	1.764	1.418	1.050	0.692	0.452
rms	1.869	1.895	1.938	2.002	2.087	2.194	2.319	2.456

ตารางที่ ก.2 (ต่อ)

เฟส \ ระยะ (m)	8	9	10	11	12	13	14	15
0, 180	0.792	1.185	1.586	1.971	2.324	2.637	2.905	3.123
5, 185	1.061	1.483	1.898	2.290	2.647	2.962	3.228	3.444
10, 190	1.334	1.772	2.195	2.591	2.949	3.262	3.525	3.735
15, 195	1.604	2.050	2.476	2.872	3.228	3.537	3.795	3.999
20, 200	1.867	2.316	2.741	3.134	3.484	3.787	4.037	4.233
25, 205	2.123	2.569	2.990	3.375	3.717	4.011	4.252	4.438
30, 210	2.360	2.800	3.212	3.588	3.919	4.202	4.431	4.606
35, 215	2.581	3.011	3.411	3.773	4.091	4.360	4.577	4.739
40, 220	2.782	3.198	3.583	3.929	4.232	4.485	4.687	4.836
45, 225	2.967	3.365	3.732	4.060	4.344	4.580	4.766	4.899
50, 230	3.126	3.504	3.849	4.155	4.419	4.635	4.803	4.921
55, 235	3.263	3.617	3.938	4.221	4.462	4.657	4.806	4.907
60, 240	3.375	3.703	3.997	4.254	4.471	4.644	4.772	4.856
65, 245	3.463	3.761	4.027	4.256	4.446	4.596	4.703	4.768
70, 250	3.524	3.790	4.025	4.225	4.388	4.512	4.597	4.643
75, 255	3.559	3.792	3.994	4.162	4.296	4.394	4.457	4.483
80, 260	3.568	3.766	3.933	4.069	4.173	4.244	4.283	4.290
85, 265	3.549	3.710	3.841	3.944	4.017	4.061	4.076	4.064
90, 270	3.505	3.627	3.722	3.790	3.832	3.848	3.840	3.808
95, 275	3.431	3.514	3.571	3.604	3.614	3.602	3.570	3.519
100, 280	3.339	3.382	3.401	3.398	3.376	3.337	3.281	3.211
105, 285	3.215	3.217	3.198	3.160	3.106	3.039	2.960	2.872
110, 290	3.067	3.030	2.972	2.899	2.814	2.720	2.618	2.513
115, 295	2.897	2.819	2.724	2.617	2.501	2.380	2.257	2.134
120, 300	2.709	2.592	2.460	2.318	2.173	2.026	1.882	1.743
125, 305	2.498	2.342	2.175	2.001	1.826	1.655	1.492	1.338
130, 310	2.272	2.079	1.877	1.672	1.470	1.277	1.094	0.927
135, 315	2.029	1.801	1.566	1.333	1.106	0.892	0.695	0.517
140, 320	1.772	1.511	1.247	0.988	0.742	0.516	0.322	0.188
145, 325	1.502	1.212	0.925	0.651	0.408	0.248	0.275	0.416
150, 330	1.228	0.916	0.620	0.373	0.293	0.432	0.631	0.821
155, 335	0.956	0.639	0.387	0.357	0.553	0.796	1.029	1.233
160, 340	0.699	0.428	0.398	0.621	0.904	1.179	1.426	1.638
165, 345	0.489	0.415	0.641	0.956	1.271	1.563	1.820	2.037
170, 350	0.424	0.615	0.949	1.300	1.634	1.936	2.199	2.418
175, 355	0.557	0.890	1.268	1.640	1.985	2.294	2.561	2.781
rms	2.598	2.737	2.867	2.981	3.074	3.142	3.184	3.199

ตารางที่ ก.2 (ต่อ)

เฟส \ ระยะ (m)	16	17	18	19	20	21	22	23
0, 180	3.292	3.411	3.484	3.514	3.505	3.463	3.394	3.303
5, 185	3.607	3.720	3.784	3.805	3.786	3.734	3.653	3.550
10, 190	3.893	3.998	4.054	4.065	4.036	3.974	3.882	3.769
15, 195	4.148	4.245	4.292	4.294	4.256	4.183	4.082	3.958
20, 200	4.374	4.462	4.500	4.492	4.444	4.362	4.252	4.119
25, 205	4.569	4.647	4.675	4.658	4.601	4.510	4.391	4.251
30, 210	4.727	4.794	4.813	4.786	4.721	4.621	4.495	4.438
35, 215	4.848	4.905	4.913	4.877	4.804	4.697	4.564	4.411
40, 220	4.932	4.977	4.975	4.931	4.849	4.737	4.598	4.440
45, 225	4.982	5.016	5.004	4.951	4.862	4.744	4.601	4.439
50, 230	4.989	5.011	4.989	4.928	4.833	4.710	4.564	4.400
55, 235	4.961	4.971	4.939	4.870	4.770	4.643	4.494	4.330
60, 240	4.895	4.892	4.851	4.775	4.670	4.540	4.390	4.226
65, 245	4.792	4.777	4.726	4.644	4.534	4.403	4.253	4.090
70, 250	4.651	4.624	4.565	4.477	4.364	4.231	4.083	3.923
75, 255	4.476	4.437	4.369	4.276	4.161	4.028	3.882	3.726
80, 260	4.268	4.217	4.141	4.043	3.927	3.795	3.652	3.501
85, 265	4.026	3.964	3.881	3.779	3.662	3.532	3.394	3.249
90, 270	3.755	3.682	3.592	3.487	3.370	3.244	3.111	2.974
95, 275	3.451	3.368	3.272	3.165	3.049	2.927	2.801	2.672
100, 280	3.129	3.036	2.935	2.826	2.712	2.595	2.475	2.356
105, 285	2.776	2.675	2.568	2.459	2.348	2.237	2.126	2.017
110, 290	2.404	2.294	2.184	2.075	1.968	1.863	1.762	1.664
115, 295	2.013	1.896	1.782	1.674	1.571	1.474	1.383	1.297
120, 300	1.611	1.487	1.371	1.264	1.167	1.078	0.997	0.923
125, 305	1.195	1.065	0.948	0.844	0.752	0.671	0.601	0.541
130, 310	0.775	0.640	0.522	0.421	0.336	0.264	0.206	0.158
135, 315	0.361	0.230	0.130	0.089	0.119	0.166	0.206	0.236
140, 320	0.187	0.278	0.376	0.460	0.525	0.572	0.604	0.621
145, 325	0.565	0.696	0.803	0.885	0.943	0.981	1.000	1.003
150, 330	0.986	1.122	1.228	1.304	1.354	1.381	1.387	1.376
155, 335	1.404	1.541	1.643	1.714	1.755	1.770	1.763	1.738
160, 340	1.813	1.948	2.046	2.110	2.141	2.145	2.126	2.087
165, 345	2.212	2.345	2.438	2.494	2.515	2.508	2.475	2.422
170, 350	2.593	2.722	2.809	2.856	2.868	2.849	2.804	2.738
175, 355	2.953	3.078	3.158	3.196	3.198	3.167	3.110	3.031
rms	3.188	3.152	3.097	3.022	2.932	2.831	2.719	2.603

ตารางที่ ก.2 (ต่อ)

เฟส \ ระยะ (m)	24	25	26	27	28	29	30	31
0, 180	3.195	3.074	2.944	2.810	2.673	2.537	2.402	2.271
5, 185	3.430	3.298	3.157	3.011	2.863	2.716	2.572	2.431
10, 190	3.638	3.495	3.343	3.187	3.030	2.874	2.720	2.571
15, 195	3.818	3.665	3.504	3.340	3.174	3.009	2.848	2.691
20, 200	3.970	3.809	3.640	3.468	3.294	3.123	2.955	2.792
25, 205	4.093	3.925	3.749	3.570	3.391	3.214	3.041	2.873
30, 210	4.184	4.010	3.829	3.645	3.461	3.279	3.102	2.930
35, 215	4.242	4.063	3.878	3.691	3.503	3.319	3.139	2.965
40, 220	4.268	4.086	3.898	3.708	3.519	3.333	3.152	2.977
45, 225	4.264	4.080	3.891	3.700	3.512	3.325	3.144	2.969
50, 230	4.224	4.039	3.851	3.661	3.472	3.288	3.108	2.935
55, 235	4.153	3.970	3.783	3.595	3.409	3.227	3.051	2.881
60, 240	4.051	3.870	3.686	3.502	3.320	3.142	2.969	2.804
65, 245	3.918	3.741	3.561	3.382	3.205	3.033	2.866	2.706
70, 250	3.755	3.582	3.409	3.236	3.066	2.900	2.740	2.587
75, 255	3.563	3.397	3.231	3.065	2.903	2.746	2.594	2.448
80, 260	3.345	3.187	3.029	2.872	2.719	2.571	2.428	2.291
85, 265	3.101	2.952	2.803	2.657	2.514	2.376	2.244	2.117
90, 270	2.834	2.695	2.557	2.422	2.291	2.164	2.043	1.927
95, 275	2.543	2.415	2.288	2.166	2.047	1.933	1.824	1.720
100, 280	2.238	2.121	2.008	1.898	1.792	1.691	1.595	1.504
105, 285	1.910	1.807	1.707	1.611	1.520	1.433	1.351	1.273
110, 290	1.570	1.480	1.395	1.314	1.237	1.165	1.097	1.033
115, 295	1.216	1.141	1.071	1.005	0.944	0.887	0.834	0.785
120, 300	0.857	0.796	0.741	0.692	0.646	0.605	0.567	0.532
125, 305	0.489	0.444	0.405	0.371	0.342	0.317	0.294	0.275
130, 310	0.121	0.091	0.068	0.050	0.037	0.028	0.021	0.016
135, 315	0.257	0.269	0.275	0.275	0.271	0.264	0.255	0.244
140, 320	0.627	0.624	0.613	0.597	0.577	0.553	0.528	0.502
145, 325	0.994	0.975	0.947	0.915	0.878	0.839	0.798	0.757
150, 330	1.352	1.317	1.273	1.224	1.171	1.116	1.061	1.005
155, 335	1.699	1.648	1.589	1.524	1.456	1.385	1.315	1.245
160, 340	2.032	1.966	1.892	1.812	1.728	1.643	1.558	1.475
165, 345	2.354	2.273	2.183	2.088	1.990	1.891	1.793	1.696
170, 350	2.655	2.560	2.457	2.348	2.236	2.123	2.012	1.903
175, 355	2.935	2.827	2.710	2.588	2.463	2.338	2.215	2.094
rms	2.482	2.361	2.24	2.122	2.007	1.895	1.788	1.686

ตารางที่ ก.2 (ต่อ)

เฟส \ ระยะ (m)	32	33	34	35	36	37	38	39
0, 180	2.144	2.023	1.907	1.796	1.692	1.594	1.501	1.414
5, 185	2.295	2.165	2.040	1.923	1.811	1.706	1.607	1.514
10, 190	2.427	2.289	2.158	2.033	1.915	1.804	1.699	1.601
15, 195	2.541	2.396	2.259	2.128	2.005	1.889	1.779	1.677
20, 200	2.636	2.486	2.343	2.208	2.080	1.959	1.846	1.740
25, 205	2.712	2.557	2.410	2.271	2.140	2.016	1.900	1.790
30, 210	2.766	2.608	2.459	2.317	2.183	2.057	1.938	1.827
35, 215	2.799	2.639	2.488	2.344	2.209	2.081	1.961	1.849
40, 220	2.810	2.650	2.498	2.354	2.218	2.090	1.969	1.856
45, 225	2.802	2.642	2.490	2.347	2.211	2.084	1.964	1.852
50, 230	2.770	2.612	2.462	2.320	2.186	2.060	1.942	1.831
55, 235	2.718	2.563	2.416	2.276	2.145	2.022	1.906	1.797
60, 240	2.645	2.494	2.351	2.216	2.088	1.968	1.855	1.749
65, 245	2.552	2.407	2.268	2.138	2.015	1.899	1.790	1.688
70, 250	2.440	2.300	2.168	2.044	1.926	1.816	1.712	1.614
75, 255	2.309	2.177	2.052	1.934	1.823	1.718	1.620	1.528
80, 260	2.161	2.037	1.920	1.810	1.706	1.609	1.517	1.431
85, 265	1.996	1.882	1.774	1.672	1.576	1.486	1.402	1.322
90, 270	1.817	1.713	1.614	1.522	1.435	1.353	1.276	1.204
95, 275	1.622	1.528	1.441	1.358	1.280	1.208	1.139	1.075
100, 280	1.418	1.336	1.259	1.187	1.120	1.056	0.997	0.941
105, 285	1.200	1.130	1.065	1.004	0.947	0.894	0.844	0.797
110, 290	0.973	0.917	0.864	0.815	0.769	0.726	0.685	0.647
115, 295	0.739	0.696	0.656	0.619	0.584	0.551	0.521	0.493
120, 300	0.501	0.471	0.444	0.419	0.396	0.374	0.354	0.335
125, 305	0.257	0.242	0.228	0.215	0.204	0.193	0.184	0.175
130, 310	0.013	0.012	0.011	0.011	0.011	0.012	0.013	0.013
135, 315	0.232	0.220	0.207	0.194	0.182	0.171	0.159	0.149
140, 320	0.476	0.449	0.424	0.399	0.375	0.352	0.330	0.310
145, 325	0.716	0.676	0.637	0.600	0.564	0.531	0.499	0.469
150, 330	0.950	0.897	0.845	0.796	0.749	0.705	0.663	0.623
155, 335	1.176	1.110	1.046	0.985	0.928	0.873	0.821	0.773
160, 340	1.393	1.315	1.239	1.167	1.099	1.035	0.974	0.917
165, 345	1.602	1.511	1.425	1.342	1.264	1.190	1.120	1.055
170, 350	1.797	1.695	1.598	1.505	1.418	1.335	1.257	1.184
175, 355	1.978	1.866	1.759	1.657	1.560	1.469	1.384	1.303
rms	1.59	1.498	1.412	1.33	1.254	1.182	1.114	1.052

ตารางที่ ก.2 (ต่อ)

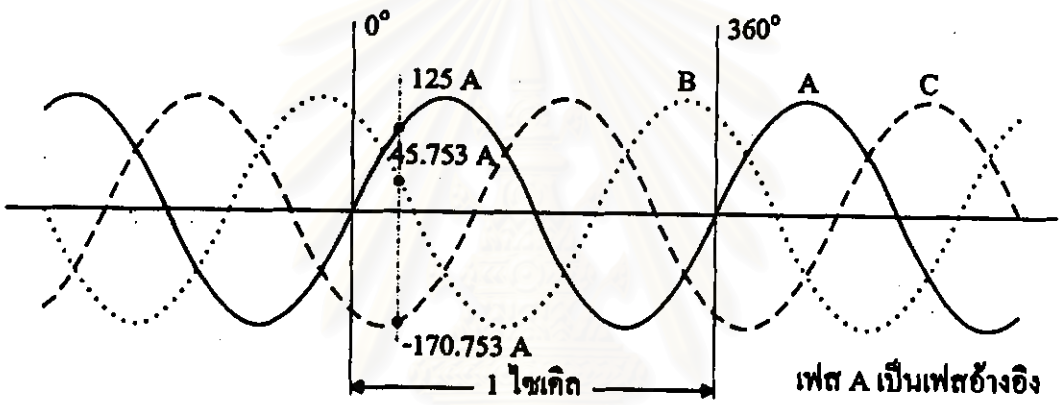
เฟส \ ระยะ (m)	40	41	42	43	44	45	46	47
0, 180	1.332	1.256	1.184	1.117	1.055	0.996	0.942	0.890
5, 185	1.427	1.345	1.268	1.197	1.130	1.068	1.009	0.955
10, 190	1.509	1.423	1.342	1.267	1.196	1.130	1.068	1.011
15, 195	1.580	1.490	1.406	1.327	1.253	1.184	1.120	1.059
20, 200	1.640	1.547	1.459	1.377	1.301	1.230	1.163	1.100
25, 205	1.688	1.592	1.502	1.418	1.340	1.266	1.198	1.133
30, 210	1.722	1.624	1.533	1.447	1.367	1.293	1.223	1.157
35, 215	1.743	1.644	1.552	1.465	1.385	1.309	1.238	1.172
40, 220	1.751	1.652	1.559	1.472	1.391	1.315	1.244	1.188
45, 225	1.746	1.648	1.555	1.469	1.388	1.312	1.242	1.176
50, 230	1.727	1.629	1.538	1.453	1.373	1.298	1.229	1.163
55, 235	1.695	1.600	1.510	1.427	1.348	1.275	1.207	1.143
60, 240	1.650	1.557	1.471	1.389	1.313	1.242	1.176	1.113
65, 245	1.593	1.503	1.420	1.341	1.268	1.200	1.135	1.075
70, 250	1.523	1.438	1.358	1.283	1.213	1.148	1.087	1.029
75, 255	1.442	1.362	1.286	1.215	1.149	1.087	1.030	0.975
80, 260	1.350	1.275	1.205	1.139	1.077	1.019	0.965	0.914
85, 265	1.248	1.179	1.114	1.053	0.996	0.943	0.893	0.846
90, 270	1.137	1.074	1.015	0.960	0.908	0.859	0.814	0.772
95, 275	1.015	0.959	0.907	0.858	0.812	0.768	0.728	0.690
100, 280	0.889	0.840	0.794	0.751	0.711	0.674	0.639	0.606
105, 285	0.753	0.712	0.673	0.637	0.604	0.572	0.542	0.515
110, 290	0.612	0.579	0.548	0.519	0.492	0.466	0.443	0.420
115, 295	0.466	0.441	0.418	0.396	0.376	0.357	0.339	0.322
120, 300	0.318	0.302	0.286	0.272	0.258	0.246	0.234	0.223
125, 305	0.166	0.159	0.151	0.145	0.138	0.132	0.126	0.121
130, 310	0.014	0.015	0.016	0.017	0.017	0.018	0.018	0.019
135, 315	0.138	0.129	0.120	0.112	0.104	0.097	0.090	0.084
140, 320	0.290	0.272	0.255	0.240	0.225	0.211	0.198	0.186
145, 325	0.440	0.414	0.389	0.366	0.344	0.324	0.305	0.288
150, 330	0.586	0.552	0.519	0.489	0.460	0.434	0.409	0.386
155, 335	0.727	0.685	0.645	0.608	0.573	0.540	0.510	0.481
160, 340	0.863	0.813	0.766	0.722	0.680	0.642	0.606	0.573
165, 345	0.993	0.936	0.882	0.831	0.784	0.740	0.699	0.661
170, 350	1.115	1.051	0.990	0.934	0.881	0.832	0.786	0.743
175, 355	1.228	1.157	1.091	1.029	0.972	0.917	0.867	0.820
rms	0.992	0.937	0.886	0.837	0.792	0.75	0.71	0.673

ตารางที่ ก.2 (ต่อ)

เฟส \ ระยะ (m)	48	49	50
0, 180	0.843	0.798	0.756
5, 185	0.903	0.856	0.811
10, 190	0.957	0.906	0.859
15, 195	1.003	0.950	0.901
20, 200	1.042	0.987	0.936
25, 205	1.073	1.017	0.964
30, 210	1.096	1.038	0.985
35, 215	1.110	1.052	0.998
40, 220	1.116	1.057	1.003
45, 225	1.114	1.056	1.001
50, 230	1.102	1.045	0.991
55, 235	1.083	1.027	0.974
60, 240	1.055	1.000	0.949
65, 245	1.019	0.967	0.917
70, 250	0.976	0.925	0.878
75, 255	0.925	0.877	0.833
80, 260	0.867	0.822	0.781
85, 265	0.802	0.761	0.723
90, 270	0.732	0.695	0.660
95, 275	0.655	0.622	0.591
100, 280	0.575	0.546	0.519
105, 285	0.489	0.464	0.441
110, 290	0.399	0.380	0.361
115, 295	0.306	0.292	0.278
120, 300	0.212	0.202	0.193
125, 305	0.116	0.111	0.106
130, 310	0.019	0.019	0.019
135, 315	0.078	0.073	0.068
140, 320	0.175	0.165	0.156
145, 325	0.271	0.256	0.242
150, 330	0.364	0.344	0.326
155, 335	0.455	0.430	0.407
160, 340	0.541	0.512	0.485
165, 345	0.625	0.591	0.560
170, 350	0.703	0.666	0.630
175, 355	0.776	0.734	0.696
rms	0.639	0.608	0.58

2. ตัวอย่างการคำนวณค่าความหนาแน่นฟลักซ์แม่เหล็กใต้สายส่งจ่ายพลังงานไฟฟ้า

ตัวอย่างที่นำมาแสดงนี้เป็นระบบเดียวกันกับการคำนวณค่าความเข้มสนามไฟฟ้า โดยใช้รูป ก.1 เหมือนกัน และแทนค่าในสมการที่ 2.11 เพื่อหาค่าความหนาแน่นฟลักซ์แม่เหล็กซึ่งสร้างโดยสายตัวนำแต่ละเส้น โดยจะต้องคิดผลของรูปคลื่นกระแสที่มีมุมเฟสนำและตามกันอยู่ 120° ดังรูปที่ ก.3 จะต้องแทนค่ากระแสไฟฟ้าด้วยค่าจริงในตำแหน่งมุมเฟสที่พิจารณา จากรูปถึงแม้ว่าจะมีกระแสไฟฟ้าไหลในวงจรต่อเฟสอยู่ 500 A แต่เนื่องจากเป็นระบบสายควบ 4 เส้น ดังนั้นในสายตัวนำแต่ละเส้นจึงมีกระแสไฟฟ้าไหลอยู่ 125 A ณ ตำแหน่ง 45° กระแสไฟฟ้าที่เฟส A มีค่า 125 A ประกอบด้วยสายตัวนำเส้นที่ 1-4 เฟส B มีค่า 45.753 A ประกอบด้วยสายตัวนำเส้นที่ 5-8 และเฟส C มีค่า -170.753 A ประกอบด้วยสายตัวนำเส้นที่ 9-12



รูปที่ ก.3 รูปคลื่นกระแสไฟฟ้าที่มีมุมเฟสนำและตามกันอยู่ 120°

$$\bar{B}(x, y) = -2I\left[\frac{(y - y')\bar{a}_x - (x - x')\bar{a}_y}{(y - y')^2 + (x - x')^2}\right]$$

เมื่อ (x, y) คือ จุดที่ต้องการพิจารณา

(x', y') คือ ตำแหน่งที่ตั้งของสายตัวนำ

I คือ กระแสไฟฟ้าที่ไหลในตัวนำแต่ละเส้น

$$\bar{B}_1(0,1) = -2(125)\left[\frac{(1-19.225)\bar{a}_x - (0-14.225)\bar{a}_y}{(1-19.225)^2 + (0-14.225)^2}\right]$$

$$= 8.524\bar{a}_x - 6.653\bar{a}_y$$

$$\bar{B}_2(0,1) = -2(125)\left[\frac{(1-18.775)\bar{a}_x - (0-14.225)\bar{a}_y}{(1-18.775)^2 + (0-14.225)^2}\right]$$

$$= 8.574\bar{a}_x - 6.861\bar{a}_y$$

$$\bar{B}_3(0,1) = -2(125)\left[\frac{(1-19.225)\bar{a}_x - (0-13.775)\bar{a}_y}{(1-19.225)^2 + (0-13.775)^2}\right]$$

$$= 8.73\bar{a}_x - 6.598\bar{a}_y$$

$$\bar{B}_4(0,1) = -2(125)\left[\frac{(1-18.775)\bar{a}_x - (0-13.775)\bar{a}_y}{(1-18.775)^2 + (0-13.775)^2}\right]$$

$$= 8.787\bar{a}_x - 6.81\bar{a}_y$$

$$\bar{B}_5(0,1) = -2(45.753)\left[\frac{(1-19.225)\bar{a}_x - (0-0.225)\bar{a}_y}{(1-19.225)^2 + (0-0.225)^2}\right]$$

$$= 5.02\bar{a}_x - 0.062\bar{a}_y$$

$$\bar{B}_6(0,1) = -2(45.753)\left[\frac{(1-18.775)\bar{a}_x - (0-0.225)\bar{a}_y}{(1-18.775)^2 + (0-0.225)^2}\right]$$

$$= 5.147\bar{a}_x - 0.065\bar{a}_y$$

$$\bar{B}_7(0,1) = -2(45.753)\left[\frac{(1-19.225)\bar{a}_x - (0+0.225)\bar{a}_y}{(1-19.225)^2 + (0+0.225)^2}\right]$$

$$= 5.02\bar{a}_x + 0.062\bar{a}_y$$

$$\bar{B}_8(0,1) = -2(45.753)\left[\frac{(1-18.775)\bar{a}_x - (0+0.225)\bar{a}_y}{(1-18.775)^2 + (0+0.225)^2}\right]$$

$$= 5.147\bar{a}_x + 0.065\bar{a}_y$$

$$\bar{B}_9(0,1) = 2(170.753)\left[\frac{(1-19.225)\bar{a}_x - (0+13.775)\bar{a}_y}{(1-19.225)^2 + (0+13.775)^2}\right]$$

$$= -11.926\bar{a}_x - 9.014\bar{a}_y$$

$$\bar{B}_{10}(0,1) = 2(170.753)\left[\frac{(1-18.775)\bar{a}_x - (0+13.775)\bar{a}_y}{(1-18.775)^2 + (0+13.775)^2}\right]$$

$$= -12.004\bar{a}_x - 9.302\bar{a}_y$$

$$\bar{B}_{11}(0,1) = 2(170.753)\left[\frac{(1-19.225)\bar{a}_x - (0+14.225)\bar{a}_y}{(1-19.225)^2+(0+14.225)^2}\right]$$

$$= -11.644\bar{a}_x - 9.089\bar{a}_y$$

$$\bar{B}_{12}(0,1) = 2(170.753)\left[\frac{(1-18.775)\bar{a}_x - (0+14.225)\bar{a}_y}{(1-18.775)^2+(0+14.225)^2}\right]$$

$$= -11.712\bar{a}_x - 9.373\bar{a}_y$$

รวม $\bar{B}_1$ ถึง $\bar{B}_{12}$ ได้ $\bar{B}(0,1) = 7.663\ \bar{a}_x - 63.7\ \bar{a}_y$ mG

$= 64.16$ mG

เช่นเดียวกับกรณีของการคำนวณค่าความเข้มสนามไฟฟ้า คือจะต้องหาค่า $\bar{B}(0,1)$ ที่ตำแหน่งมุมเฟสอื่นๆบนรูปคลื่นกระแสจนครบ 1 ไซเคิลของรูปคลื่นกระแส ในที่นี้ได้แบ่งรูปคลื่นกระแสออกทีละ 5° ได้ค่ากระแสไฟฟ้าที่ตำแหน่งมุมเฟสต่างๆ ดังแสดงในตารางที่ ก.3 จากการคำนวณค่าความหนาแน่นฟลักซ์แม่เหล็กทั้งหมดได้ผลดังแสดงในตารางที่ ก.4

ตารางที่ ก.3 ค่ากระแสไฟฟ้าจริงที่ใช้คำนวณของระบบ 500 kV ขณะมีกระแสต่อเฟส 500 A (สายควบ 4 เส้น)

มุม \ เฟส	A	B	C
0	0.000	153.093	-153.093
5	15.407	144.807	-160.214
10	30.697	135.419	-166.116
15	45.753	125.000	-170.753
20	60.461	113.630	-174.091
25	74.709	101.395	-176.104
30	88.388	88.388	-176.777
35	101.395	74.709	-176.104
40	113.630	60.461	-174.091
45	125.000	45.753	-170.753
50	135.419	30.697	-166.116
55	144.807	15.407	-160.214
60	153.093	0.000	-153.093
65	160.214	-15.407	-144.807
70	166.116	-30.697	-135.419
75	170.753	-45.753	-125.000
80	174.091	-60.461	-113.630
85	176.104	-74.709	-101.395
90	176.777	-88.388	-88.388
95	176.104	-101.395	-74.709
100	174.091	-113.630	-60.461
105	170.753	-125.000	-45.753
110	166.116	-135.419	-30.697
115	160.214	-144.807	-15.407
120	153.093	-153.093	0.000
125	144.807	-160.214	15.407
130	135.419	-166.116	30.697
135	125.000	-170.753	45.753
140	113.630	-174.091	60.461
145	101.395	-176.104	74.709
150	88.388	-176.777	88.388
155	74.709	-176.104	101.395
160	60.461	-174.091	113.630
165	45.753	-170.753	125.000
170	30.697	-166.116	135.419
175	15.407	-160.214	144.807

มุม \ เฟส	A	B	C
180	0.000	-153.093	153.093
185	-15.407	-144.807	160.214
190	-30.697	-135.419	166.116
195	-45.753	-125.000	170.753
200	-60.461	-113.630	174.091
205	-74.709	-101.395	176.104
210	-88.388	-88.388	176.777
215	-101.395	-74.709	176.104
220	-113.630	-60.461	174.091
225	-125.000	-45.753	170.753
230	-135.419	-30.697	166.116
235	-144.807	-15.407	160.214
240	-153.093	0.000	153.093
245	-160.214	15.407	144.807
250	-166.116	30.697	135.419
255	-170.753	45.753	125.000
260	-174.091	60.461	113.630
265	-176.104	74.709	101.395
270	-176.777	88.388	88.388
275	-176.104	101.395	74.709
280	-174.091	113.630	60.461
285	-170.753	125.000	45.753
290	-166.116	135.419	30.697
295	-160.214	144.807	15.407
300	-153.093	153.093	0.000
305	-144.807	160.214	-15.407
310	-135.419	166.116	-30.697
315	-125.000	170.753	-45.753
320	-113.630	174.091	-60.461
325	-101.395	176.104	-74.709
330	-88.388	176.777	-88.388
335	-74.709	176.104	-101.395
340	-60.461	174.091	-113.630
345	-45.753	170.753	-125.000
350	-30.697	166.116	-135.419
355	-15.407	160.214	-144.807

ตารางที่ ก.4 ผลการคำนวณค่าความหนาแน่นฟลักซ์แม่เหล็กใต้สายส่ง 500 kV วงจรเดี่ยว 500 A

เฟส \ ระยะ (m)	0	1	2	3	4	5	6	7
0, 180	41.773	40.592	39.312	37.951	36.530	35.068	33.586	32.099
5, 185	44.936	43.749	42.470	41.120	39.719	38.286	36.839	35.395
10, 190	48.079	46.919	45.675	44.367	43.015	41.638	40.251	38.869
15, 195	51.118	50.012	48.828	47.587	46.307	45.004	43.693	42.384
20, 200	53.986	52.955	51.852	50.697	49.505	48.291	47.066	45.838
25, 205	56.629	55.690	54.684	53.629	52.537	51.422	50.290	49.148
30, 210	59.001	58.168	57.273	56.329	55.347	54.337	53.304	52.250
35, 215	61.065	60.350	59.575	58.751	57.887	56.987	56.056	55.093
40, 220	62.793	62.205	61.558	60.860	60.118	59.333	58.507	57.635
45, 225	64.160	63.706	63.192	62.626	62.009	61.341	60.620	59.842
50, 230	65.149	64.833	64.458	64.025	63.535	62.986	62.371	61.685
55, 235	65.748	65.573	65.338	65.040	64.678	64.246	63.737	63.142
60, 240	65.948	65.916	65.821	65.659	65.423	65.107	64.702	64.198
65, 245	65.748	65.859	65.903	65.873	65.762	65.560	65.255	64.839
70, 250	65.149	65.401	65.581	65.681	65.690	65.597	65.391	65.059
75, 255	64.160	64.548	64.860	65.084	65.208	65.220	65.106	64.855
80, 260	62.793	63.312	63.748	64.090	64.322	64.432	64.405	64.230
85, 265	61.065	61.707	62.260	62.711	63.043	63.243	63.296	63.191
90, 270	59.001	59.755	60.415	60.964	61.386	61.666	61.791	61.748
95, 275	56.629	57.484	58.238	58.873	59.373	59.722	59.908	59.920
100, 280	53.986	54.928	55.760	56.467	57.030	57.435	57.671	57.727
105, 285	51.118	52.128	53.021	53.781	54.391	54.837	55.109	55.198
110, 290	48.079	49.135	50.068	50.860	51.497	51.967	52.258	52.365
115, 295	44.936	46.012	46.958	47.758	48.399	48.871	49.163	49.272
120, 300	41.773	42.836	43.764	44.542	45.160	45.607	45.878	45.969
125, 305	38.693	39.702	40.574	41.294	41.855	42.249	42.471	42.520
130, 310	35.821	36.729	37.498	38.118	38.582	38.886	39.027	39.005
135, 315	33.310	34.059	34.672	35.141	35.463	35.634	35.655	35.527
140, 320	31.332	31.860	32.259	32.522	32.649	32.639	32.496	32.221
145, 325	30.056	30.308	30.437	30.441	30.322	30.082	29.727	29.262
150, 330	29.614	29.554	29.376	29.083	28.679	28.170	27.564	26.868
155, 335	30.056	29.683	29.193	28.594	27.894	27.101	26.227	25.281
160, 340	31.332	30.679	29.909	29.033	28.063	27.010	25.888	24.710
165, 345	33.310	32.434	31.442	30.348	29.165	27.909	26.595	25.239
170, 350	35.821	34.786	33.639	32.394	31.070	29.683	28.250	26.790
175, 355	38.693	37.559	36.319	34.989	33.590	32.139	30.655	29.157
rms	49.524	49.476	49.331	49.091	48.756	48.325	47.800	47.181

ตารางที่ ก.4 (ต่อ)

เฟส \ ระยะ (m)	8	9	10	11	12	13	14	15
0, 180	30.623	29.172	27.757	26.385	25.064	23.798	22.589	21.440
5, 185	33.967	32.565	31.197	29.870	28.586	27.347	26.154	25.006
10, 190	37.502	36.157	34.841	33.555	32.300	31.077	29.883	28.718
15, 195	41.086	39.802	38.536	37.287	36.054	34.835	33.628	32.432
20, 200	44.612	43.390	42.171	40.954	39.737	38.515	37.287	36.054
25, 205	47.996	46.836	45.663	44.476	43.269	42.040	40.788	39.512
30, 210	51.175	50.076	48.948	47.788	46.590	45.352	44.073	42.753
35, 215	54.095	53.057	51.974	50.840	49.650	48.403	47.097	45.736
40, 220	56.714	55.738	54.698	53.591	52.411	51.155	49.825	48.425
45, 225	58.998	58.083	57.088	56.008	54.838	53.576	52.226	50.791
50, 230	60.919	60.064	59.115	58.063	56.905	55.641	54.274	52.810
55, 235	62.453	61.660	60.755	59.733	58.591	57.328	55.949	54.462
60, 240	63.584	62.852	61.993	61.003	59.878	58.620	57.235	55.731
65, 245	64.299	63.627	62.815	61.857	60.753	59.505	58.119	56.607
70, 250	64.591	63.977	63.211	62.289	61.209	59.975	58.594	57.079
75, 255	64.456	63.900	63.180	62.293	61.239	60.024	58.655	57.146
80, 260	63.896	63.395	62.720	61.870	60.845	59.652	58.301	56.805
85, 265	62.917	62.467	61.836	61.023	60.030	58.864	57.536	56.060
90, 270	61.530	61.127	60.538	59.762	58.802	57.666	56.366	54.917
95, 275	59.749	59.390	58.839	58.099	57.173	56.070	54.803	53.388
100, 280	57.596	57.273	56.758	56.051	55.160	54.092	52.862	51.487
105, 285	55.096	54.803	54.317	53.641	52.783	51.752	50.563	49.231
110, 290	52.283	52.009	51.545	50.896	50.069	49.075	47.928	46.645
115, 295	49.194	48.928	48.478	47.849	47.050	46.091	44.986	43.754
120, 300	45.878	45.607	45.160	44.542	43.764	42.836	41.773	40.592
125, 305	42.396	42.102	41.642	41.024	40.258	39.356	38.331	37.200
130, 310	38.822	38.483	37.992	37.359	36.593	35.706	34.711	33.625
135, 315	35.254	34.842	34.297	33.627	32.844	31.958	30.982	29.931
140, 320	31.821	31.302	30.672	29.940	29.115	28.210	27.235	26.206
145, 325	28.693	28.029	27.278	26.450	25.554	24.601	23.604	22.573
150, 330	26.091	25.244	24.335	23.374	22.372	21.340	20.287	19.226
155, 335	24.276	23.221	22.128	21.008	19.873	18.731	17.594	16.471
160, 340	23.488	22.237	20.967	19.692	18.423	17.169	15.941	14.749
165, 345	23.856	22.459	21.063	19.679	18.320	16.996	15.717	14.490
170, 350	25.317	23.848	22.395	20.972	19.589	18.257	16.983	15.774
175, 355	27.661	26.181	24.730	23.320	21.960	20.658	19.418	18.245
rms	46.469	45.664	44.768	43.783	42.712	41.563	40.342	39.057

ตารางที่ ก.4 (ต่อ)

เฟส \ ระยะ (m)	16	17	18	19	20	21	22	23
0, 180	20.350	19.319	18.346	17.428	16.564	15.751	14.987	14.268
5, 185	23.903	22.843	21.826	20.851	19.917	19.023	18.169	17.354
10, 190	27.581	26.471	25.389	24.336	23.313	22.321	21.361	20.436
15, 195	31.248	30.076	28.917	27.775	26.653	25.554	24.482	23.440
20, 200	34.814	33.572	32.331	31.094	29.870	28.661	27.476	26.318
25, 205	38.214	36.900	35.574	34.243	32.916	31.600	30.303	29.031
30, 210	41.398	40.011	38.603	37.181	35.755	34.335	32.931	31.551
35, 215	44.324	42.870	41.382	39.873	38.354	36.837	35.332	33.851
40, 220	46.961	45.443	43.883	42.293	40.688	39.081	37.485	35.911
45, 225	49.280	47.705	46.079	44.417	42.735	41.047	39.368	37.711
50, 230	51.259	49.634	47.951	46.226	44.476	42.718	40.967	39.237
55, 235	52.878	51.212	49.481	47.702	45.895	44.077	42.266	40.474
60, 240	54.122	52.424	50.655	48.834	46.981	45.115	43.254	41.414
65, 245	54.981	53.260	51.463	49.610	47.724	45.822	43.925	42.048
70, 250	55.446	53.712	51.898	50.025	48.117	46.192	44.271	42.370
75, 255	55.513	53.776	51.956	50.075	48.157	46.222	44.290	42.378
80, 260	55.182	53.451	51.636	49.760	47.845	45.912	43.982	42.073
85, 265	54.455	52.741	50.942	49.082	47.182	45.264	43.350	41.456
90, 270	53.339	51.652	49.880	48.046	46.174	44.284	42.398	40.533
95, 275	51.844	50.193	48.458	46.663	44.830	42.981	41.135	39.311
100, 280	49.985	48.378	46.690	44.944	43.161	41.364	39.572	37.800
105, 285	47.778	46.224	44.592	42.904	41.183	39.449	37.721	36.015
110, 290	45.245	43.750	42.182	40.562	38.913	37.252	35.599	33.969
115, 295	42.413	40.983	39.486	37.942	36.372	34.794	33.226	31.681
120, 300	39.312	37.951	36.530	35.068	33.586	32.099	30.623	29.172
125, 305	35.980	34.690	33.348	31.974	30.584	29.194	27.818	26.469
130, 310	32.463	31.243	29.982	28.696	27.402	26.113	24.842	23.599
135, 315	28.821	27.666	26.482	25.284	24.085	22.898	21.734	20.600
140, 320	25.134	24.034	22.920	21.803	20.695	19.607	18.546	17.521
145, 325	21.520	20.458	19.398	18.349	17.321	16.322	15.357	14.433
150, 330	18.165	17.115	16.084	15.081	14.113	13.184	12.300	11.461
155, 335	15.372	14.303	13.274	12.288	11.351	10.466	9.636	8.859
160, 340	13.599	12.500	11.456	10.471	9.548	8.689	7.893	7.161
165, 345	13.323	12.221	11.189	10.229	9.342	8.528	7.785	7.110
170, 350	14.635	13.570	12.581	11.668	10.830	10.065	9.369	8.738
175, 355	17.142	16.110	15.148	14.254	13.427	12.663	11.958	11.309
rms	37.722	36.346	34.944	33.529	32.113	30.708	29.325	27.974

ตารางที่ ก.4 (ต่อ)

เฟส \ ระยะ (m)	24	25	26	27	28	29	30	31
0, 180	13.593	12.958	12.361	11.801	11.273	10.777	10.309	9.869
5, 185	16.576	15.837	15.133	14.465	13.831	13.230	12.660	12.120
10, 190	19.545	18.690	17.872	17.090	16.344	15.634	14.958	14.317
15, 195	22.432	21.459	20.523	19.626	18.768	17.949	17.169	16.427
20, 200	25.192	24.102	23.051	22.042	21.074	20.149	19.267	18.428
25, 205	27.792	26.589	25.427	24.308	23.236	22.210	21.231	20.298
30, 210	30.203	28.893	27.625	26.405	25.233	24.112	23.042	22.022
35, 215	32.402	30.992	29.627	28.311	27.048	25.839	24.684	23.585
40, 220	34.369	32.868	31.414	30.012	28.665	27.376	26.145	24.973
45, 225	36.087	34.504	32.970	31.491	30.070	28.710	27.412	26.175
50, 230	37.540	35.886	34.283	32.737	31.252	29.831	28.474	27.182
55, 235	38.717	37.004	35.343	33.741	32.202	30.729	29.323	27.985
60, 240	39.608	37.846	36.139	34.492	32.911	31.397	29.953	28.578
65, 245	40.205	38.408	36.666	34.987	33.373	31.830	30.357	28.956
70, 250	40.504	38.684	36.920	35.219	33.586	32.024	30.534	29.117
75, 255	40.502	38.672	36.899	35.189	33.548	31.978	30.482	29.059
80, 260	40.199	38.372	36.602	34.895	33.258	31.693	30.200	28.782
85, 265	39.597	37.786	36.032	34.341	32.719	31.169	29.692	28.289
90, 270	38.703	36.920	35.193	33.530	31.936	30.412	28.961	27.583
95, 275	37.522	35.779	34.093	32.470	30.914	29.428	28.014	26.671
100, 280	36.064	34.375	32.741	31.169	29.662	28.225	26.857	25.559
105, 285	34.343	32.718	31.147	29.637	28.191	26.812	25.500	24.256
110, 290	32.373	30.823	29.326	27.887	26.512	25.201	23.955	22.774
115, 295	30.171	28.705	27.292	25.935	24.639	23.405	22.233	21.123
120, 300	27.757	26.385	25.064	23.798	22.589	21.440	20.350	19.319
125, 305	25.155	23.884	22.663	21.494	20.381	19.324	18.323	17.377
130, 310	22.392	21.229	20.113	19.049	18.036	17.077	16.170	15.316
135, 315	19.504	18.451	17.445	16.488	15.581	14.724	13.916	13.156
140, 320	16.535	15.593	14.697	13.849	13.049	12.295	11.588	10.925
145, 325	13.552	12.716	11.927	11.185	10.489	9.838	9.231	8.664
150, 330	10.672	9.930	9.237	8.592	7.992	7.435	6.920	6.444
155, 335	8.137	7.469	6.851	6.283	5.761	5.283	4.845	4.445
160, 340	6.489	5.875	5.316	4.810	4.351	3.937	3.565	3.230
165, 345	6.502	5.955	5.465	5.028	4.639	4.294	3.989	3.718
170, 350	8.168	7.654	7.190	6.772	6.394	6.053	5.743	5.462
175, 355	10.710	10.158	9.649	9.178	8.743	8.339	7.964	7.614
rms	26.661	25.394	24.175	23.008	21.896	20.838	19.834	18.883

ตารางที่ ก.4 (ต่อ)

เฟส \ ระยะ (m)	32	33	34	35	36	37	38	39
0, 180	9.454	9.063	8.694	8.346	8.016	7.705	7.411	7.132
5, 185	11.609	11.126	10.668	10.234	9.824	9.436	9.068	8.719
10, 190	13.708	13.131	12.584	12.066	11.575	11.110	10.669	10.251
15, 195	15.723	15.054	14.419	13.818	13.248	12.708	12.197	11.713
20, 200	17.630	16.872	16.154	15.473	14.828	14.217	13.638	13.090
25, 205	19.412	18.571	17.773	17.016	16.300	15.621	14.979	14.370
30, 210	21.053	20.134	19.261	18.434	17.651	16.910	16.208	15.544
35, 215	22.540	21.548	20.607	19.715	18.871	18.073	17.317	16.602
40, 220	23.859	22.802	21.799	20.849	19.950	19.100	18.296	17.535
45, 225	25.000	23.885	22.828	21.827	20.880	19.984	19.136	18.335
50, 230	25.954	24.789	23.686	22.641	21.652	20.717	19.833	18.998
55, 235	26.714	25.508	24.365	23.284	22.261	21.294	20.380	19.517
60, 240	27.272	26.034	24.861	23.751	22.702	21.710	20.773	19.888
65, 245	27.626	26.364	25.170	24.040	22.972	21.963	21.009	20.109
70, 250	27.771	26.496	25.289	24.147	23.068	22.049	21.086	20.178
75, 255	27.708	26.428	25.217	24.072	22.990	21.968	21.004	20.094
80, 260	27.436	26.161	24.955	23.815	22.738	21.722	20.763	19.858
85, 265	26.957	25.697	24.505	23.378	22.315	21.312	20.365	19.472
90, 270	26.276	25.039	23.870	22.766	21.723	20.740	19.813	18.939
95, 275	25.398	24.194	23.056	21.981	20.968	20.012	19.112	18.262
100, 280	24.329	23.166	22.068	21.032	20.055	19.134	18.266	17.448
105, 285	23.079	21.966	20.915	19.925	18.991	18.111	17.283	16.503
110, 290	21.657	20.602	19.606	18.668	17.785	16.953	16.170	15.434
115, 295	20.075	19.085	18.152	17.274	16.447	15.669	14.937	14.249
120, 300	18.346	17.428	16.564	15.751	14.987	14.268	13.593	12.958
125, 305	16.486	15.646	14.857	14.115	13.418	12.763	12.149	11.572
130, 310	14.511	13.755	13.045	12.379	11.754	11.168	10.618	10.103
135, 315	12.442	11.773	11.147	10.560	10.010	9.496	9.015	8.565
140, 320	10.305	9.726	9.184	8.679	8.207	7.767	7.357	6.973
145, 325	8.137	7.646	7.190	6.767	6.373	6.007	5.668	5.352
150, 330	6.004	5.598	5.223	4.878	4.559	4.265	3.993	3.742
155, 335	4.079	3.746	3.441	3.163	2.910	2.678	2.467	2.274
160, 340	2.929	2.659	2.418	2.202	2.009	1.837	1.684	1.548
165, 345	3.478	3.266	3.078	2.911	2.762	2.629	2.510	2.403
170, 350	5.206	4.971	4.756	4.558	4.375	4.205	4.046	3.898
175, 355	7.289	6.985	6.700	6.432	6.181	5.945	5.722	5.512
rms	17.985	17.136	16.336	15.582	14.871	14.201	13.570	12.976

ตารางที่ ก.4 (ต่อ)

เฟส \ ระยะ (m)	40	41	42	43	44	45	46	47
0, 180	6.867	6.617	6.379	6.154	5.939	5.735	5.541	5.357
5, 185	8.388	8.075	7.778	7.496	7.227	6.973	6.731	6.500
10, 190	9.856	9.480	9.125	8.787	8.467	8.162	7.873	7.598
15, 195	11.254	10.819	10.407	10.016	9.645	9.293	8.959	8.641
20, 200	12.571	12.079	11.613	11.171	10.752	10.355	9.978	9.620
25, 205	13.795	13.249	12.733	12.244	11.780	11.340	10.923	10.527
30, 210	14.916	14.321	13.758	13.224	12.719	12.240	11.785	11.354
35, 215	15.925	15.285	14.679	14.105	13.562	13.047	12.559	12.096
40, 220	16.815	16.134	15.490	14.880	14.303	13.756	13.238	12.746
45, 225	17.578	16.861	16.184	15.542	14.936	14.361	13.816	13.300
50, 230	18.208	17.461	16.755	16.087	15.455	14.857	14.290	13.753
55, 235	18.700	17.929	17.200	16.510	15.858	15.241	14.656	14.102
60, 240	19.052	18.261	17.514	16.808	16.141	15.509	14.911	14.344
65, 245	19.259	18.455	17.696	16.979	16.301	15.659	15.052	14.477
70, 250	19.320	18.509	17.744	17.021	16.337	15.691	15.079	14.500
75, 255	19.235	18.423	17.657	16.934	16.250	15.604	14.992	14.414
80, 260	19.004	18.198	17.437	16.719	16.040	15.398	14.792	14.218
85, 265	18.630	17.835	17.085	16.377	15.708	15.076	14.479	13.914
90, 270	18.114	17.337	16.603	15.911	15.257	14.640	14.056	13.504
95, 275	17.462	16.707	15.996	15.324	14.691	14.092	13.527	12.993
100, 280	16.678	15.952	15.267	14.622	14.013	13.438	12.895	12.382
105, 285	15.768	15.076	14.424	13.809	13.230	12.683	12.166	11.679
110, 290	14.740	14.087	13.472	12.892	12.346	11.831	11.345	10.887
115, 295	13.601	12.992	12.419	11.879	11.370	10.891	10.439	10.012
120, 300	12.361	11.801	11.273	10.777	10.309	9.869	9.454	9.063
125, 305	11.031	10.522	10.044	9.594	9.172	8.774	8.399	8.047
130, 310	9.620	9.167	8.742	8.342	7.967	7.615	7.283	6.971
135, 315	8.143	7.748	7.378	7.032	6.706	6.401	6.114	5.845
140, 320	6.615	6.281	5.968	5.676	5.402	5.146	4.906	4.680
145, 325	5.058	4.784	4.529	4.292	4.071	3.864	3.671	3.491
150, 330	3.511	3.296	3.098	2.914	2.744	2.586	2.440	2.304
155, 335	2.097	1.935	1.787	1.652	1.528	1.414	1.309	1.213
160, 340	1.427	1.320	1.225	1.141	1.067	1.001	0.944	0.893
165, 345	2.306	2.218	2.137	2.063	1.995	1.932	1.873	1.818
170, 350	3.760	3.630	3.507	3.392	3.282	3.179	3.080	2.986
175, 355	5.313	5.125	4.946	4.777	4.616	4.464	4.318	4.180
rms	12.416	11.888	11.390	10.921	10.477	10.059	9.663	9.289

ตารางที่ ก.4 (ต่อ)

เฟส \ ระยะ (m)	48	49	50
0, 180	5.181	5.013	4.853
5, 185	6.281	6.072	5.873
10, 190	7.337	7.088	6.851
15, 195	8.339	8.052	7.779
20, 200	9.280	8.956	8.649
25, 205	10.151	9.793	9.453
30, 210	10.945	10.556	10.187
35, 215	11.657	11.240	10.843
40, 220	12.280	11.838	11.418
45, 225	12.811	12.346	11.905
50, 230	13.244	12.761	12.303
55, 235	13.577	13.079	12.607
60, 240	13.807	13.298	12.815
65, 245	13.933	13.416	12.927
70, 250	13.952	13.433	12.940
75, 255	13.866	13.347	12.855
80, 260	13.674	13.160	12.672
85, 265	13.379	12.873	12.393
90, 270	12.982	12.488	12.020
95, 275	12.487	12.009	11.556
100, 280	11.897	11.439	11.004
105, 285	11.218	10.782	10.369
110, 290	10.453	10.043	9.656
115, 295	9.610	9.229	8.870
120, 300	8.694	8.346	8.016
125, 305	7.714	7.400	7.104
130, 310	6.677	6.399	6.138
135, 315	5.592	5.353	5.128
140, 320	4.469	4.270	4.084
145, 325	3.322	3.165	3.017
150, 330	2.177	2.059	1.949
155, 335	1.124	1.043	0.968
160, 340	0.848	0.808	0.774
165, 345	1.766	1.718	1.672
170, 350	2.897	2.812	2.731
175, 355	4.048	3.922	3.801
rms	8.935	8.600	8.283

ประวัติผู้วิจัย

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