GPS/GLONASS Antennas and Ground Planes: Size and Weight Reduction Perspectives.

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Results, perspectives and probable limitations of GPS/GLONASS/GALILEO broadband multipath-protected antennas

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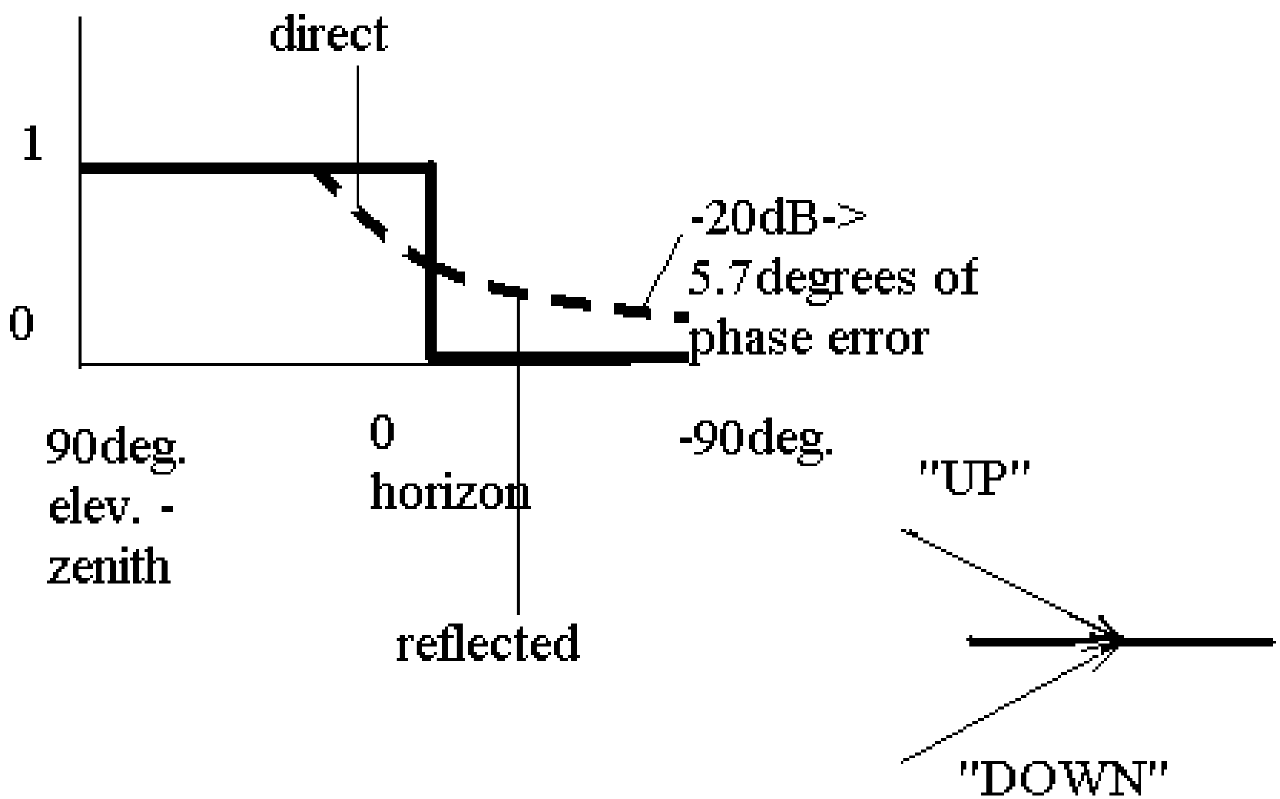
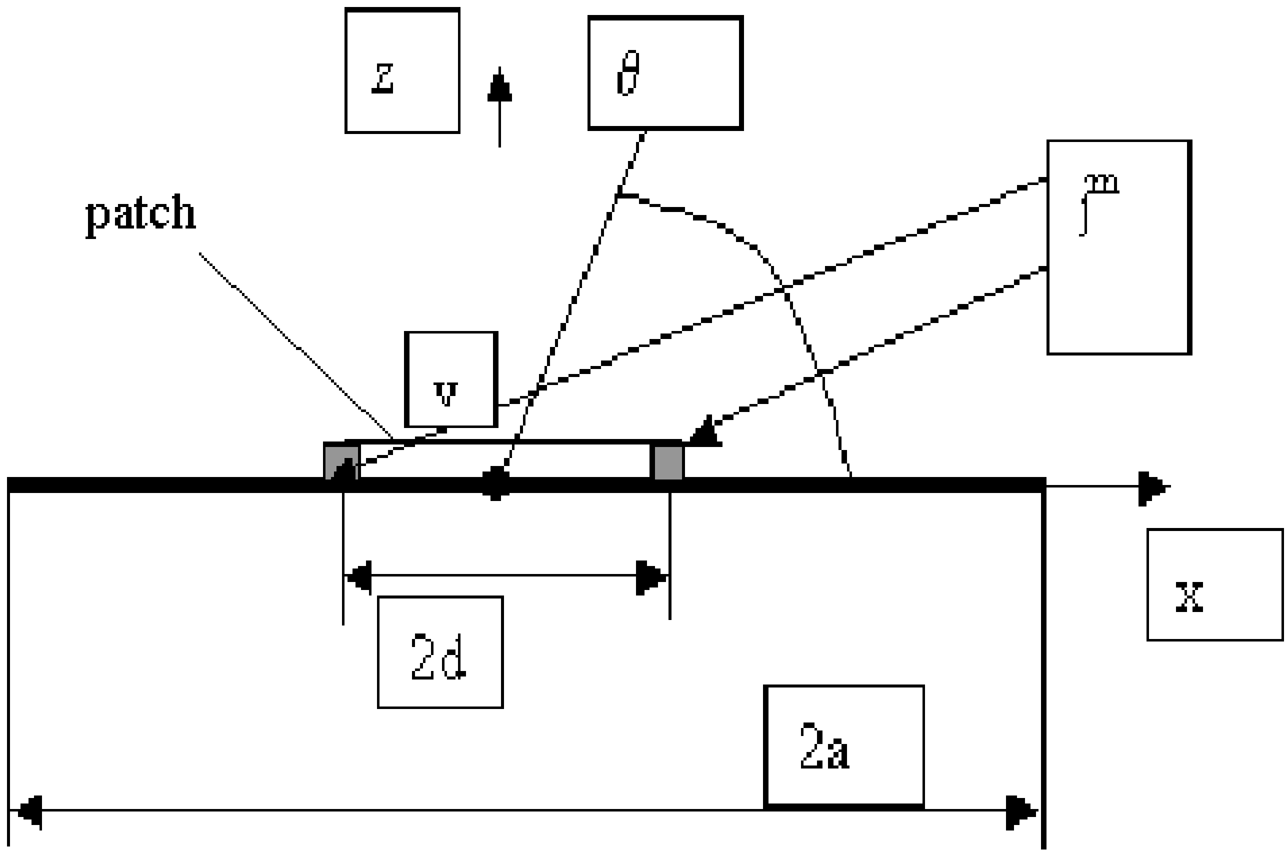
1. General considerations

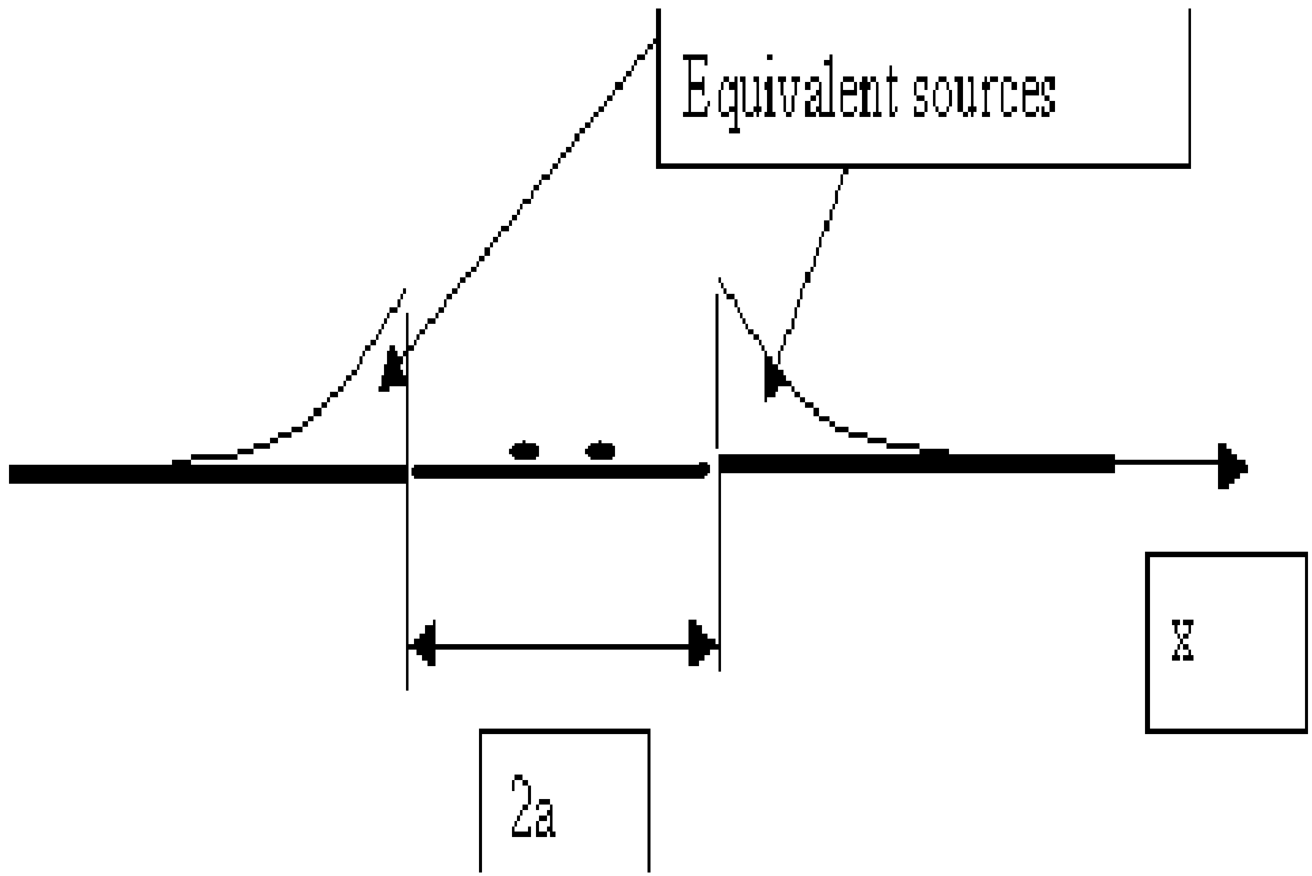


-Transmitting mode; Natural scale:

-2D problems; 1 wavelength = 20cm



1. Coventional Ground Planes



1.a)Flat Metal GroundPlane

details of treatment

$$\vec{j}^{m} = U^{m}\delta(z)\delta(x-d)\vec{y}_0$$

$$\vec{H} = -\frac{k}{W_0}\frac{U^m}{4}H_0^{(2)}(kr)\vec{y}_0$$

$$\vec{j}^{e} = 2\left[\vec{z}_0, \vec{H}\ \right] = \frac{k}{W_0}\frac{U^m}{2}H_0^{(2)}(k|x-d|)\vec{x}_0 \approx \frac{k}{W_0}\frac{U^m}{2}\sqrt{\frac{2}{\pi k|x-d|}}e^{-i(k|x-d|-\frac{\pi}{4})}\vec{x}_0$$

$$E_{\theta 1} = \frac{k}{8}kU^m\sqrt{\frac{2}{\pi kr}}e^{-i(kr-\frac{\pi}{4})}\sin(\theta)\{\int_a^{\infty}\sqrt{\frac{2}{\pi k(x-d)}}e^{-i(k(x-d)-\frac{\pi}{4})}e^{ikx\cos(\theta)}dx +$$

$$\int_{-\infty}^{-a}\sqrt{\frac{2}{\pi k(|x|+d)}}e^{-i(k(|x|+d)-\frac{\pi}{4})}e^{ikx\cos(\theta)}dx\}$$

$$\int_a^{\infty}\sqrt{\frac{2}{\pi k(x-d)}}e^{-i(k(x-d)-\frac{\pi}{4})}e^{ikx\cos(\theta)}dx \approx \frac{-i}{k}A1(a-d)\frac{e^{ika\cos(\theta)}}{1-\cos(\theta)}$$

$$A1(s) = \sqrt{\frac{2}{\pi ks}}e^{-i(ks-\frac{\pi}{4})}$$

$$E_{\theta diff} = \frac{1}{8}kU^m\sqrt{\frac{2}{\pi kr}}e^{-i(kr-\frac{\pi}{4})}2\cos(kd)A1(a)\sin(\theta)\left\{\frac{e^{ika\cos(\theta)}}{1-\cos(\theta)} + \frac{e^{-ika\cos(\theta)}}{1+\cos(\theta)}\right\}$$

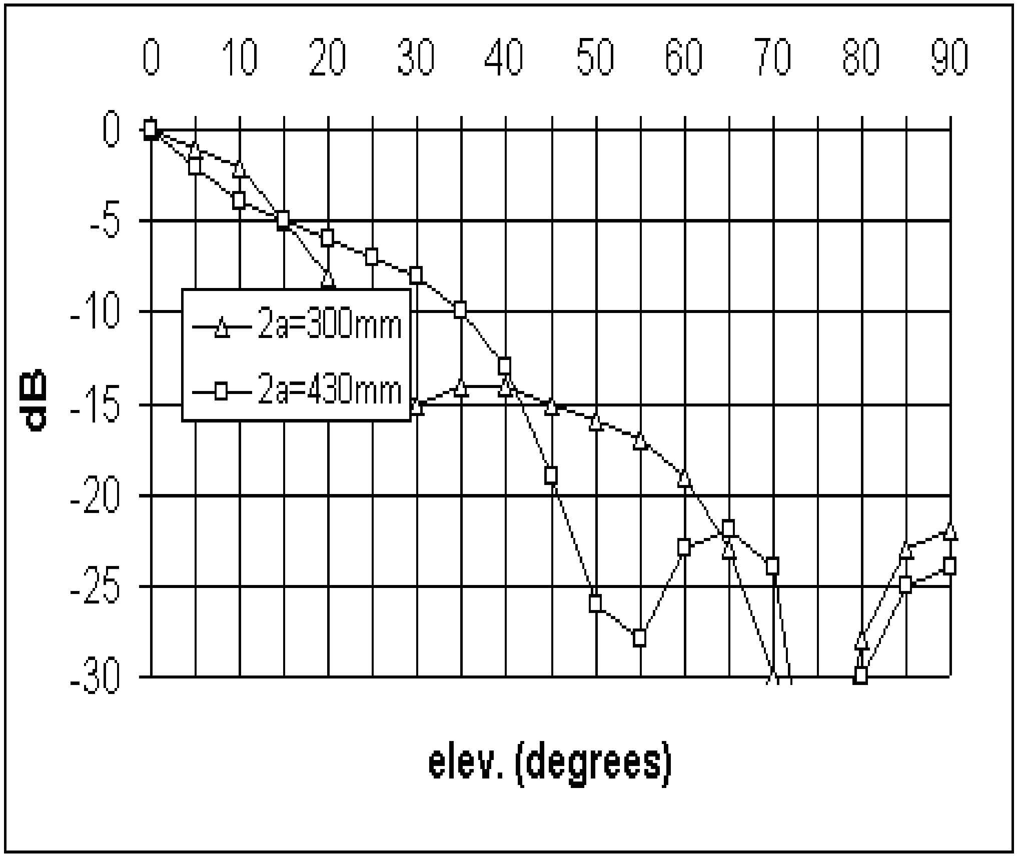
$$E_{\theta\,\mathrm{inf}} = -\frac{1}{2}kU^m\sqrt{\frac{2}{\pi kr}}e^{-i(kr-\frac{\pi}{4})}2\cos(kd\cos(\theta))$$

$$\alpha \approx f_0(0)\frac{1}{2\pi\sqrt{\frac{a}{\lambda}}}$$

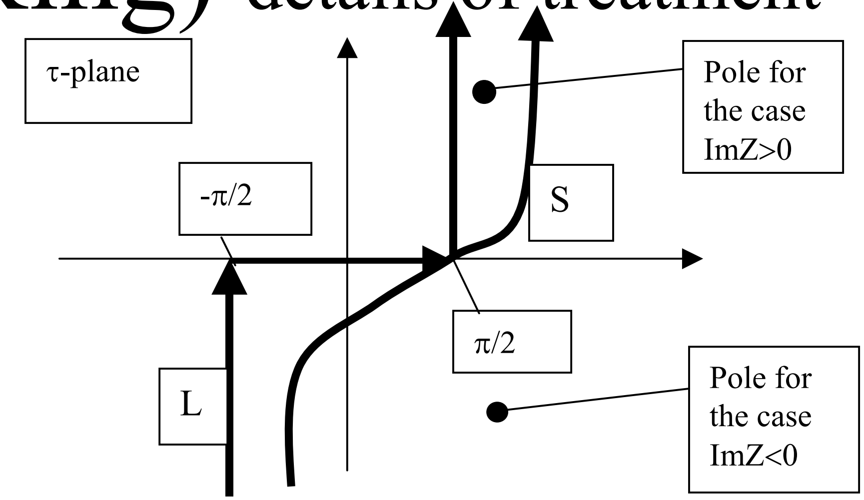
1.a)Flat Metal GroundPlane

$$j^e \approx \sqrt{\frac{1}{\left|\frac{x}{\lambda}\right|}}$$

$$\alpha \approx f_0(0)\frac{1}{2\pi\sqrt{\frac{a}{\lambda}}}$$



1.b)Impedance Ground Plane (e.g.Choke Ring) details of treatment



$$\vec{j}^{\,m} = \vec{y}_0 \frac{U^m}{2\pi}\delta(z-l)\int_{-\infty}^{\infty} e^{-iu(x-d)}du$$

$$E_x^- = \frac{1}{2}\frac{U^m}{2\pi}\int_{-\infty}^{\infty} e^{-i(u(x-d)-\zeta(z-l))}du$$

$$H_y^- = -\omega\varepsilon_0 \frac{1}{2}\frac{U^m}{2\pi}\int_{-\infty}^{\infty} \frac{e^{-i(u(x-d)-\zeta(z-l))}}{\zeta}du$$

$$E_x^+ = \int_{-\infty}^{\infty} E_0^+(u) e^{-i(u(x-d)-\zeta(z-l))}du$$

$$H_y^+ = \omega\varepsilon_0 \int_{-\infty}^{\infty} E_0^+(u)\frac{e^{-i(u(x-d)-\zeta(z-l))}}{\zeta}du$$

$$\zeta = \sqrt{k^2-u^2};\ \mathrm{Re}\,\zeta \geq 0$$

$$E_x^{total} = -ZH_y^{total}$$

$$E_x^+(u) = -\frac{1}{2}\frac{U^m}{2\pi}\frac{1-Z\dfrac{\omega\varepsilon_0}{\zeta}}{1+Z\dfrac{\omega\varepsilon_0}{\zeta}}e^{-i\zeta l}$$

$$E_x^{total}(x)_{z=0} = \frac{U^m}{2\pi}Z\omega\varepsilon_0\int_{-\infty}^{\infty}\frac{1}{\zeta+Z\omega\varepsilon_0}e^{-iu(x-d)}du$$

$$u = k\sin(\tau)$$

$$\mathrm{Im}(Z)\angle 0$$

$$E_x^{total}(x) \approx -\frac{kU^m}{\sqrt{2\pi}}e^{i\frac{3\pi}{4}}\frac{W_0}{Z}\frac{e^{-ik|x-d|}}{(k|x-d|)^{3/2}}$$

$$H_y^{total} = -\frac{1}{Z}E_x^{total}(x) \approx \frac{kU^m}{W_0\sqrt{2\pi}}e^{i\frac{3\pi}{4}}\left(\frac{W_0}{Z}\right)^2\frac{e^{-ik|x-d|}}{(k|x-d|)^{3/2}}$$

$$E_{\theta 1} = -\frac{k}{4}\frac{kU^m}{\sqrt{2\pi}}e^{i\frac{3\pi}{4}}\frac{W_0}{Z}\sqrt{\frac{2}{\pi kr}}e^{-i(kr-\frac{\pi}{4})}\left(\frac{W_0}{Z}\sin(\theta)-1\right)$$

$$\left\{\int_a^{\infty}\frac{e^{-ik|x-d|}}{(k|x-d|)^{3/2}}e^{ikx\cos(\theta)}dx + \int_{-\infty}^{-a}\frac{e^{-ik|x-d|}}{(k|x-d|)^{3/2}}e^{ikx\cos(\theta)}dx\right\}$$

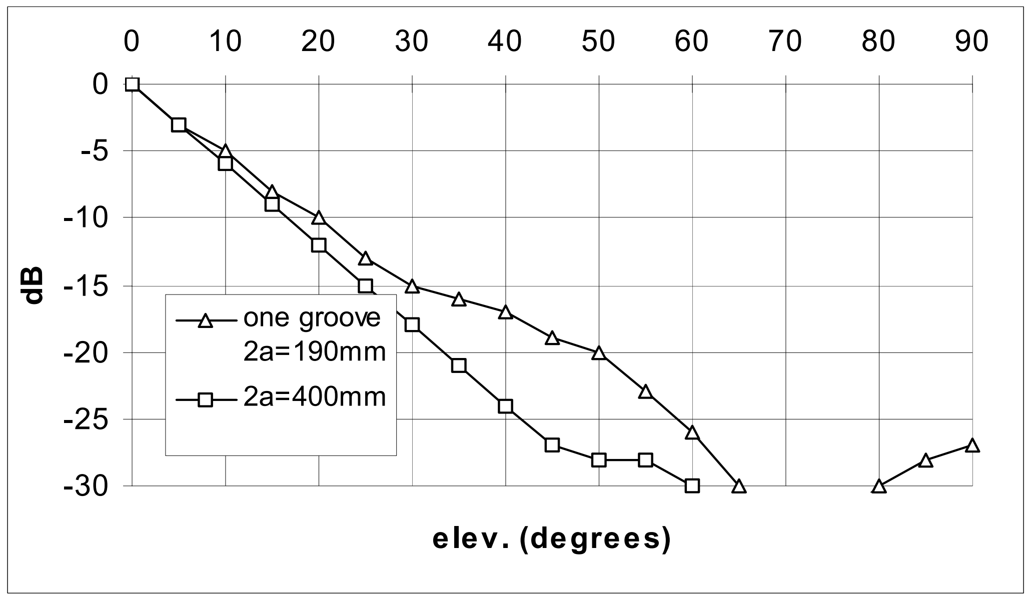
$$\int_a^{\infty}\frac{1}{(k(x-d))^{\frac{3}{2}}}e^{-ik(x-d)}e^{ikx\cos(\theta)}dx \approx \frac{-i}{k}A2(a-d)\frac{e^{ika\cos(\theta)}}{1-\cos(\theta)}$$

$$A2(s) = \frac{1}{(ks)^{\frac{3}{2}}}e^{-iks};\alpha \approx f_0(0)\frac{\dfrac{W_0}{Z}\left(\dfrac{W_0}{Z}-1\right)}{(2\pi)^2\left(\dfrac{a}{\lambda}\right)^{3/2}}$$

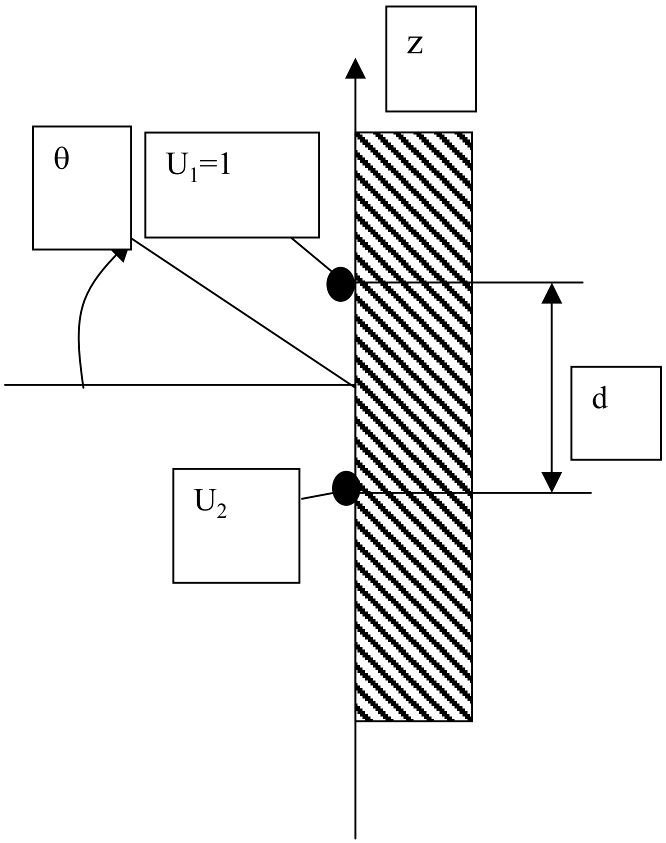
1.b)Impedance Ground Plane (e.g.Choke Ring)

$$\left| j^{equi.e} \right| = \left| \frac{j^{equi.m}}{Z} \right| \approx \frac{1}{(x/\lambda)^{3/2}}$$

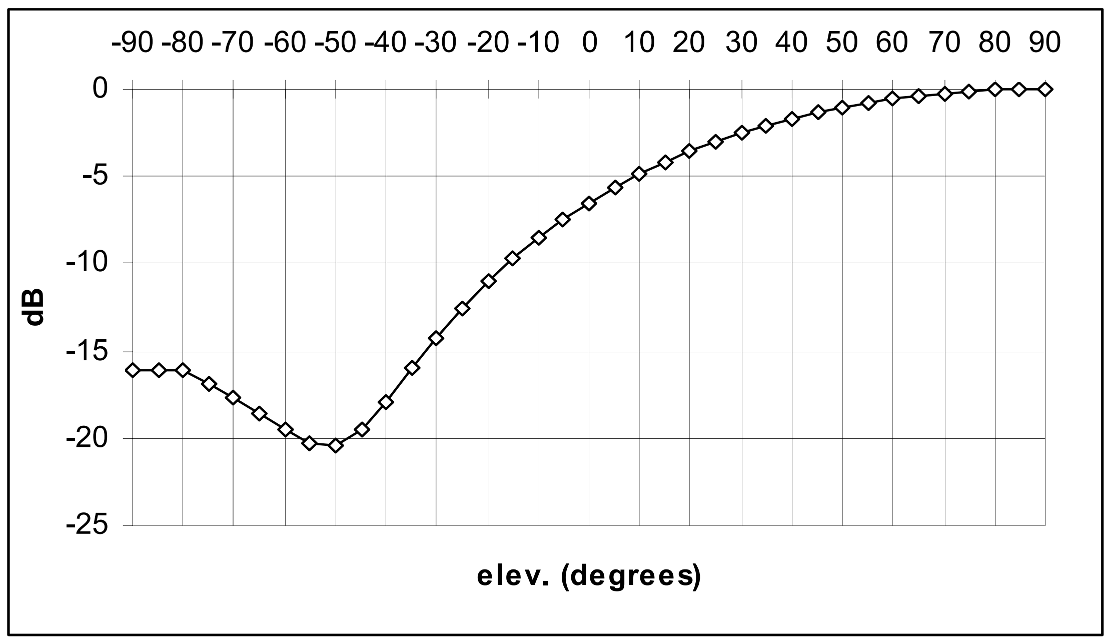
$$\alpha \approx f_0(0) \frac{\frac{W_0}{Z}\left(\frac{W_0}{Z} - 1\right)}{(2\pi)^2 \left(\frac{a}{\lambda}\right)^{3/2}}$$



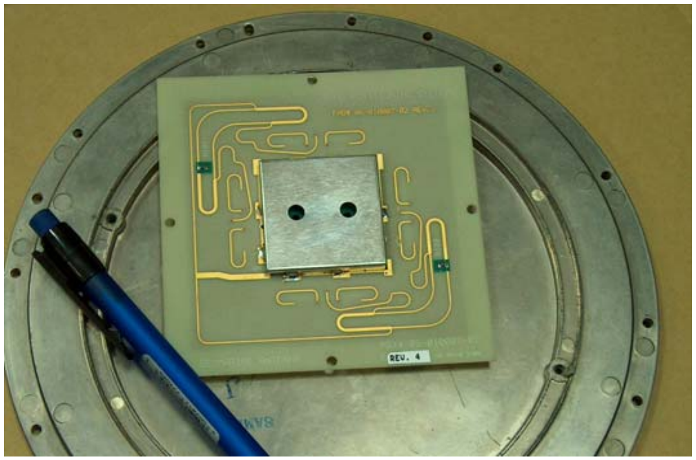
3.Small-size vertical structures

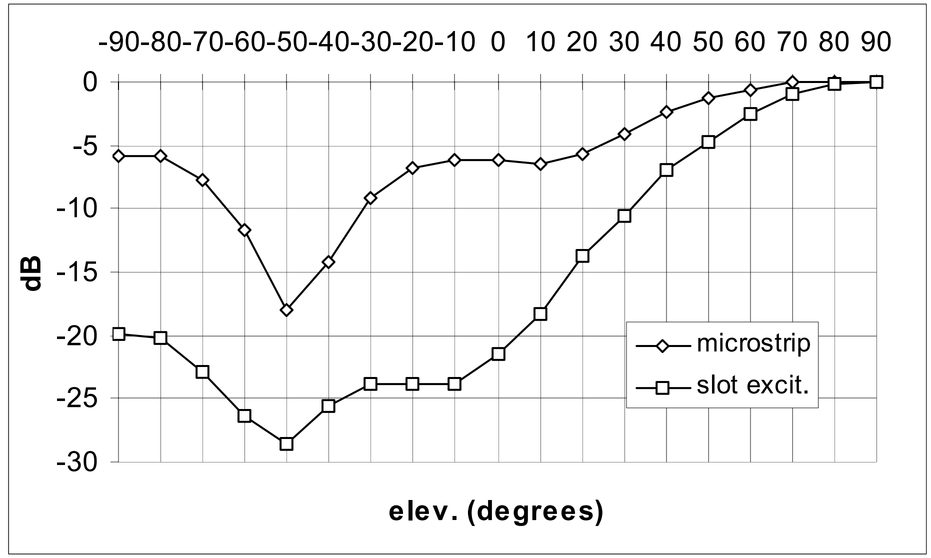


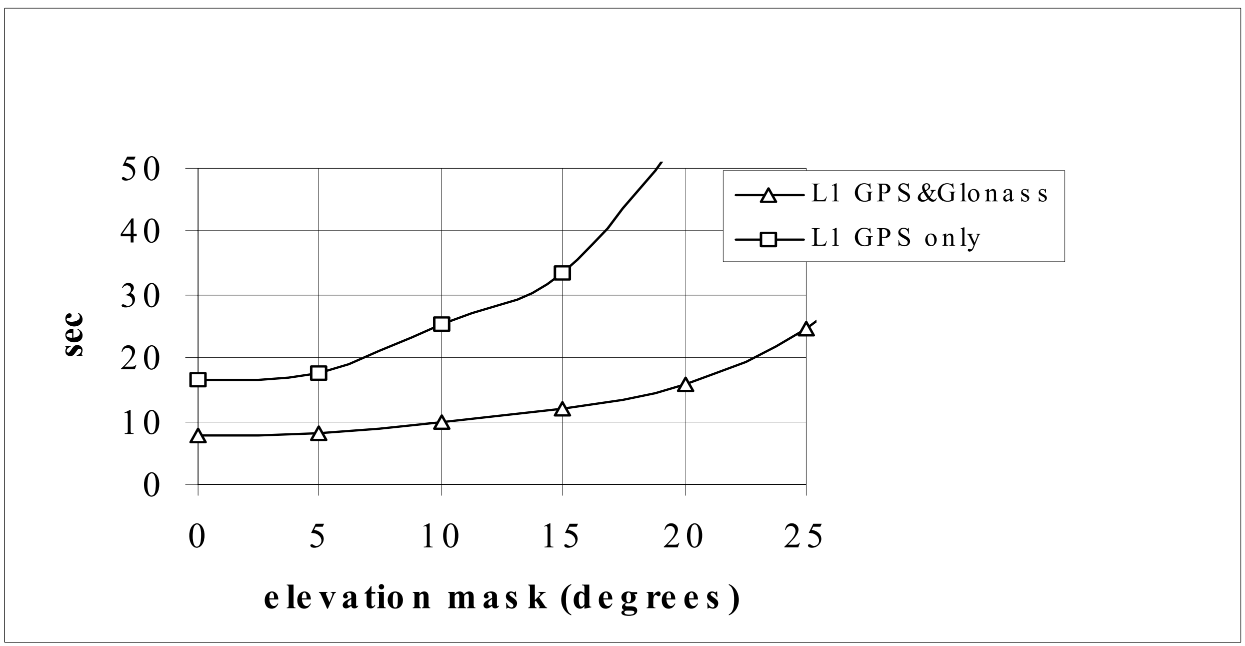
$$d << wavelength(20cm)$$



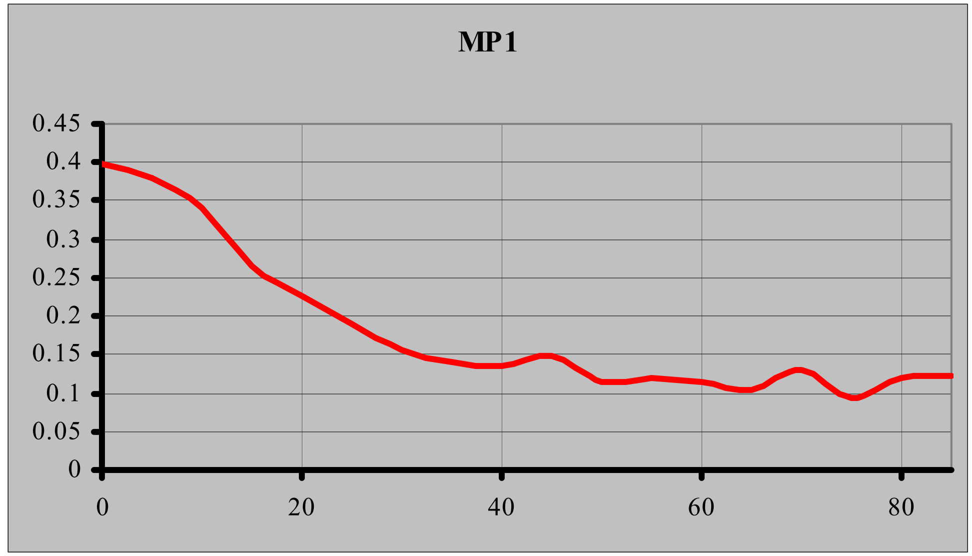
3.Practical results

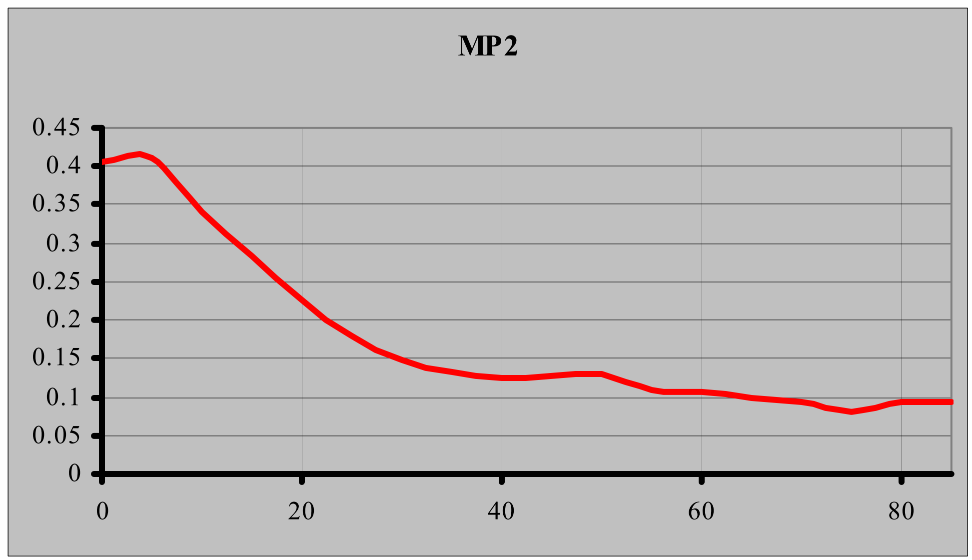




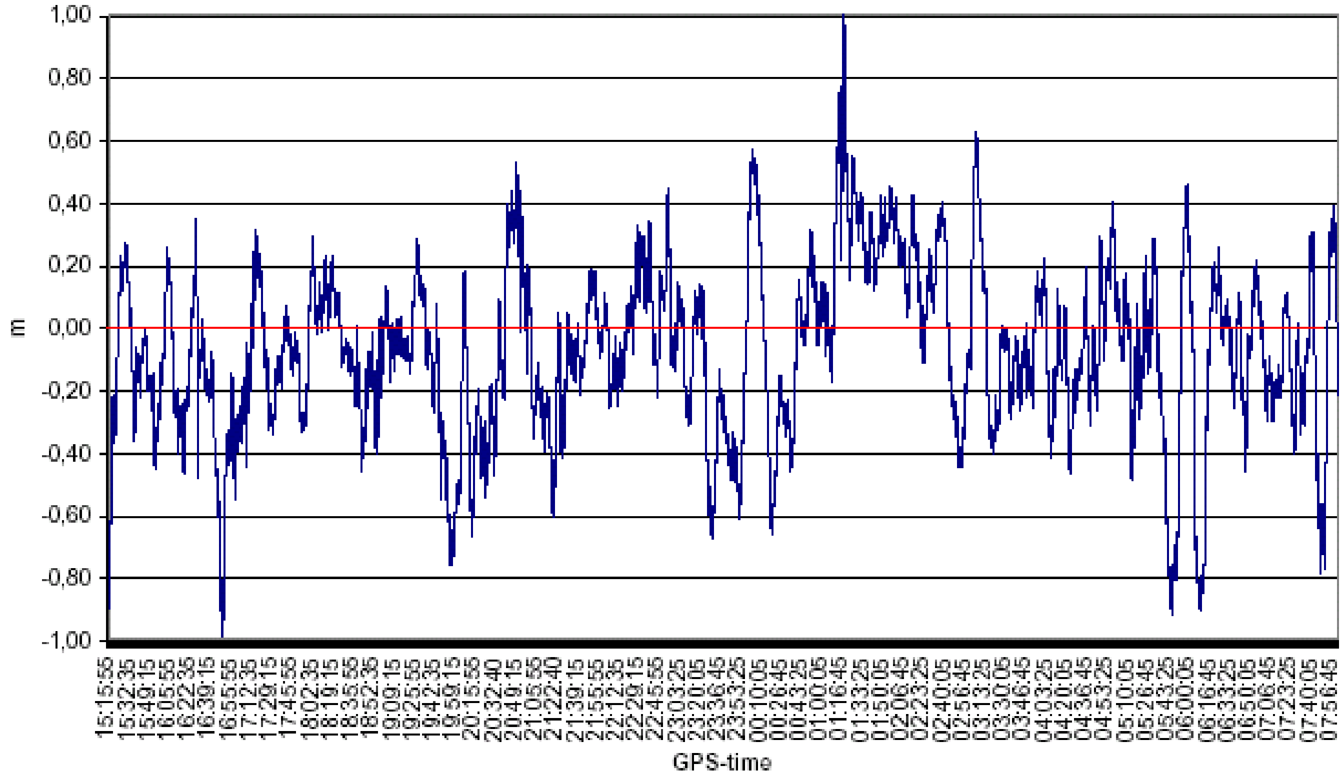



-90 -75 -60 -45 -30 -15 0 15 30 45 60 75 90
0
-5
-10
-15
-20
-25
dB
elev. (degrees)


MP1
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
20
40
60
80


MP2
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
20
40
60
80

Height: Divergence to known value
Hannover - 09.12.03-10.12.03



Conclusion

- Very small size multipath protected antennas might become a reality at least for RT positioning with about 1 cm accuracy though “superdirectivity” phenomena as theoretical limit should be considered .