Source: **Motorola**
Title: **Polarization Effects & Path Statistics for the Spatial Channel Model**
Document for: **Discussion**

1. SUMMARY

Handsets and small devices do not have adequate space for a 2 to 4 element linear array. For this reason polarized antennas are likely to be the only practical implementation. This contribution presents a description of the correlation observed from the use of polarized antennas in various scenarios. The following details are described:

- The effect of different Branch Power Ratios (BPR) and angles of arrival.
- The power dependency of BPR and its effect when combined with an angle of arrival model.
- Related to the path powers, the dependency of the r-value is shown to impact the dynamic range of the path powers. Adjustments in the r-values are suggested.

Plots and analysis are shown to describe these effects.

2. EFFECTS OF POLARIZED ANTENNAS IN THE SPATIAL CHANNEL MODEL

The illustration in Figure 1 shows a cross-polarized antenna configuration, as in [1] where a narrow angle of arrival spread is received from an average angle β. In this description, the angle of arrival is considered to have an angle spread as given by a probability density function, p(β).

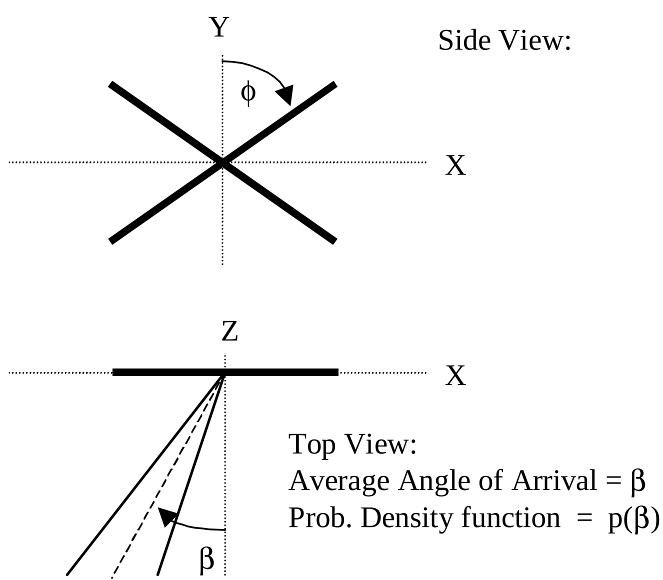

Figure 1 Angle of Arrival and Angle Spread definitions for polarized antennas

The angle spread probability distribution is a Laplacian distribution given by equation 1.

$$P(\beta) = \frac{1}{\sigma\sqrt{2}} \exp\left[\frac{-\sqrt{2}|\beta|}{\sigma}\right] \tag{1}$$

Modifying the equations in [1] gives the complex correlation coefficient in equation 2.

$$\rho(\phi, \beta, \Gamma) = \left[\frac{-\tan^2(\phi) \cdot E[\cos^2(\beta)] + \Gamma}{\tan^2(\phi) \cdot E[\cos^2(\beta)] + \Gamma}\right] \tag{2}$$

Where $E[\cos^2(\beta)]$ is the expected value calculated from p(β). Γ, also called XPD, is the ratio of the power contained in the vertically polarized component to the power contained in the horizontally polarized component. When considering a single resolvable path, the XPD is equivalent to the BPR.

Branch power ratio describes the coupling from the channel to the subscriber antennas which are at +/- 45^o in this experiment. Figure 2 is obtained by transmitting a vertically polarized signal which suffers depolarizing effects in the environment and received with the cross polarized subscriber antennas. The effect of the antenna orientation produces a significant change in the correlation between branches. Notice that for the case of Dual-pol antennas with no spatial separation, the correlation coefficient has only a real part (i.e. the imaginary part is exactly 0 for all angles of arrival).

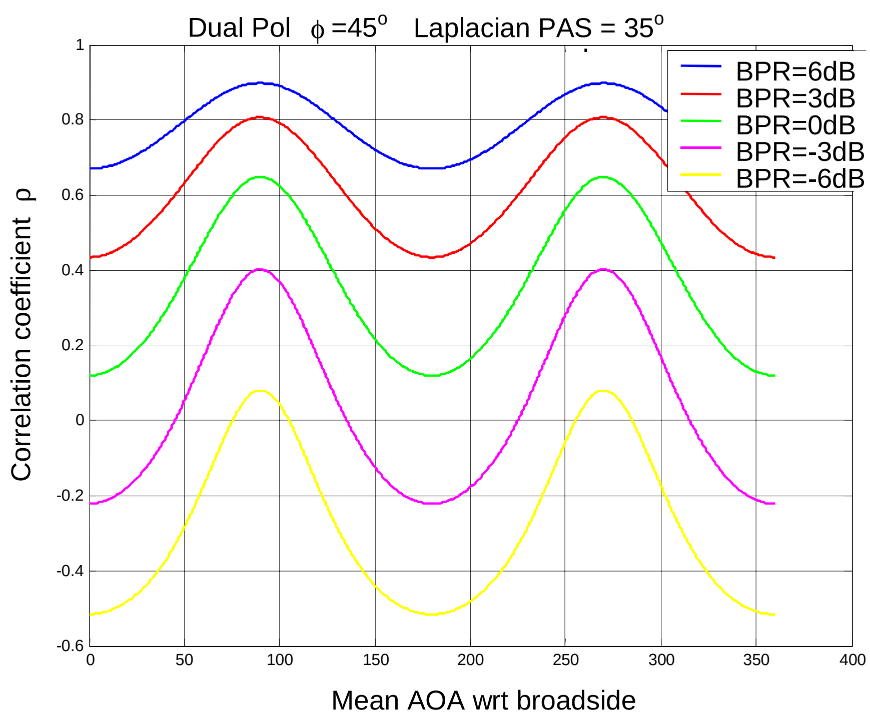

Figure 2, Correlation of +/- 45^o antennas with given BPR

It is evident from Figure 2 that a for a vertically polarized transmit signal in a channel with an BPR of 6dB, the magnitude of the receive antenna complex correlation coefficient is quite high at all angles of arrival. The angle spread was a 35 degree Laplacian.

Figure 3 shows that the BPR (measured in h & v) for a single narrow angle of arrival, which is approximately equivalent to a single path, is a strong function of the relative per path power [2]. As seen in the data set, the weakest signals have a mean BPR ≅ 0, and a sigma of about 6 dB. With stronger powers, the BPR increases to about 6 dB for the data points having the strongest power. Notice that the sigma is also somewhat lower for the strongest relative powers. By modeling the BPR with the linear regression line shown in the figure: y = 0.34*x + 7.2, the relationship between the power in a given path to the amount of polarization cross coupling can be modeled.

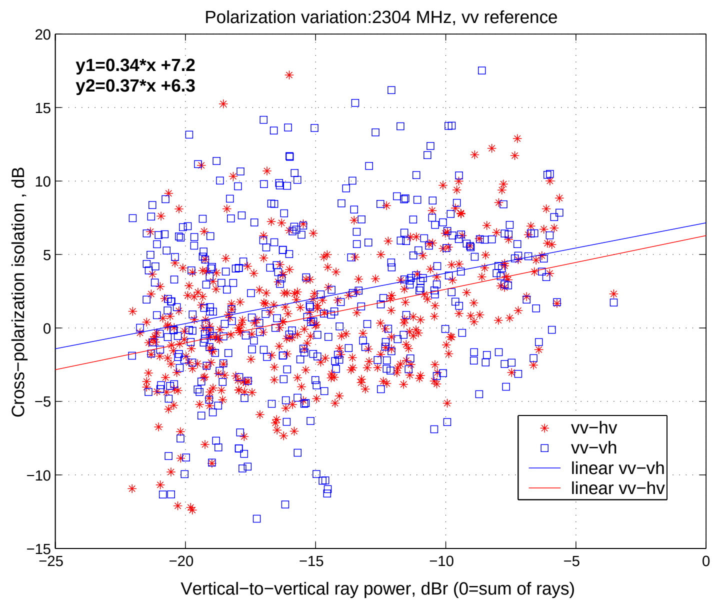

Figure 3, Power Dependency on Branch Power Ratio (V/H)

By modeling, the polarization cross coupling as a function of power, a more complete picture of the polarized model can be seen through simulations. In Figure 2, the average magnitude of the complex correlation coefficient is simulated for a number of different subscriber antenna orientations. In Figure 3, the polarization cross coupling is described by the relative path power in each ray. This dependency of BPR on relative power is incorporated into a simulation of correlation coefficient.

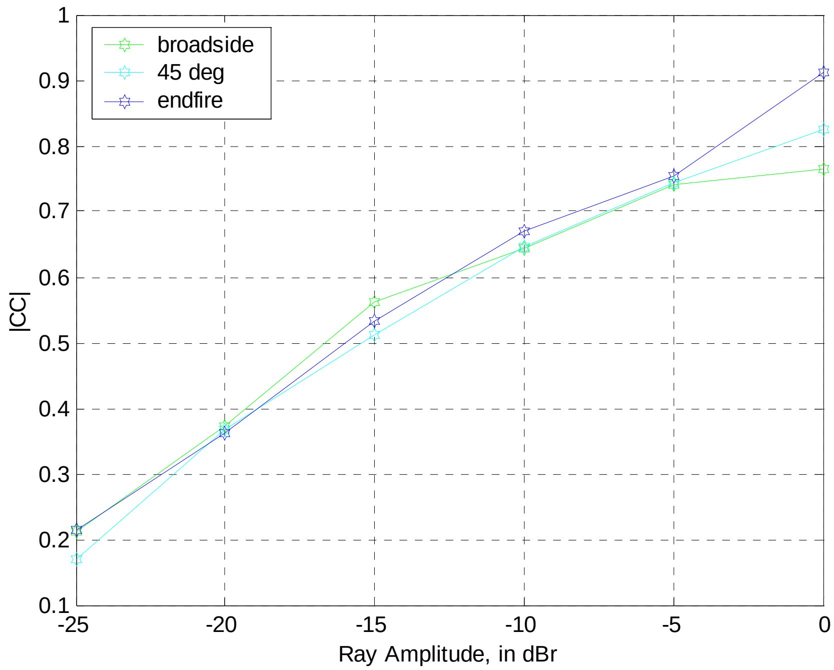

Figure 4, Simulated Correlation using BPR(Pr) for Various Subscriber Orientations

Figure 4 shows the results of the correlation between the cross polarized subscriber antennas from the channel simulation as a function of relative power. As seen in the figure, the correlation is relatively low for weak powers, however for the strongest powers, the correlation is very high. This is important because the most useful signals in a multi-antenna system are those with the strongest powers.

3. PATH POWERS IN THE CURRENT SCM MODEL

Since a number of effects, including polarization BPR, are shown to be a function of the relative path power, it is important to evaluate the dynamic range and probability distribution of the path powers. In the following figures, the path powers are shown to be a strong function of the r-value. Since the low r-values produce a dramatic reduction in dynamic range, it is likely that these values need to be revisited, and perhaps increased to be more in line with measurements. Since a number of factors and thresholds can effect the r-value estimate, it would be more precise to set the value based on other parameters as well, such as the effective dynamic range of the path powers. Figure 5 illustrates the Dynamic Range (max-min power of a set of 6 path powers) for a given r-value.

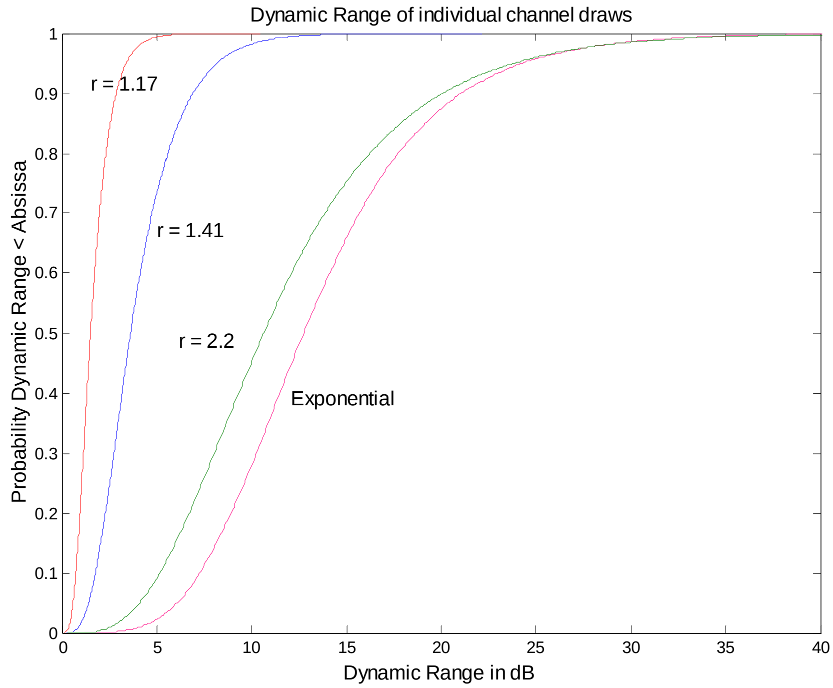

Figure 5, CDF of Dynamic Range for 6 path Channel draws

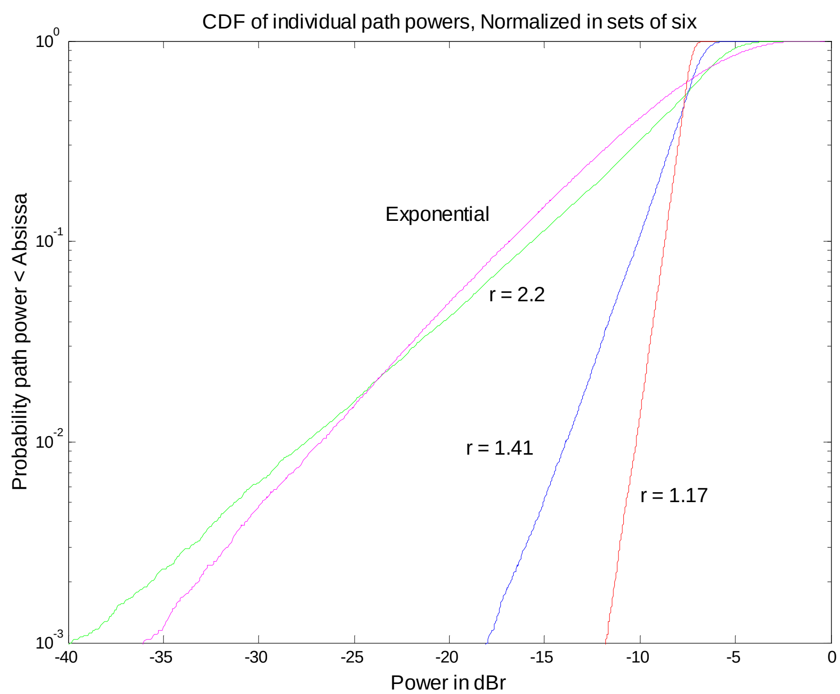

Figure 6, CDF of Normalized Path Powers

As shown, for an r-value of 1.17, the powers are confined to a very narrow range. This is not typical of measurements, rather something closer to the exponential is generally observed which would require an r-value closer to 2.2, as shown in Figure 6. Note that changing the r-value doesn't effect the exponential shape of the average PDP since the r-value is used to set both the time of arrival distribution as well as the path powers, so that the ratio, i.e. the exponential slope of the PDP is preserved.

4. CONCLUSION

In this contribution, the magnitude of the complex correlation coefficient is evaluated for +/- 45^o polarized subscriber antennas in various situations, having a vertically polarized BS array.

Simulations show that the correlation is quite high, especially for the strong paths, which have a high BPR. This is important because these are the useful signals for Multi-antenna transmission.

Additional experiments with polarized antennas will be worthwhile to evaluate cases such as subscribers having unequal antenna patterns.

Regarding Path Powers, the dynamic range is severely limited for low values of the r-ratio. Comparisons should be made to measured data that include distributions of path powers. It is likely that the r-values need to be higher to allow a more reasonable ray path power distribution.

5. REFERENCES

[1] Kozono, S. et al, "Base Station Polarization Diversity Reception for Mobile Radio," IEEE Trans. on Vehicular Technology, Vol. VT-33, No. 4, November 1984

[2] Motorola, “UE Angle of Arrival Distribution”, SCM-047, SCM Ad-hoc meeting, Seattle, USA, September 20th 2002.

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