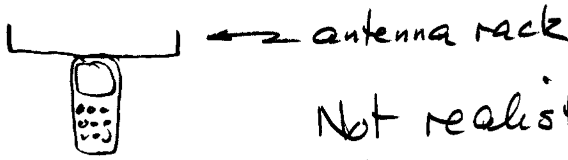
9.4 Improvement by Diversity

- The signal strength varies rapidly in the cluster of scatterers. Why not equip the mobile with a second antenna a wavelength or two from the first antenna? That would give it two chances at a strong signal.

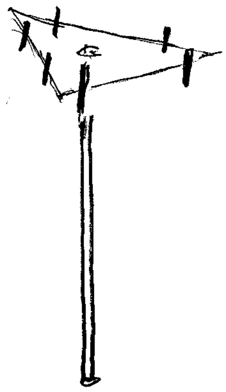


Not realistic on a handset when $\lambda = 30$ cm

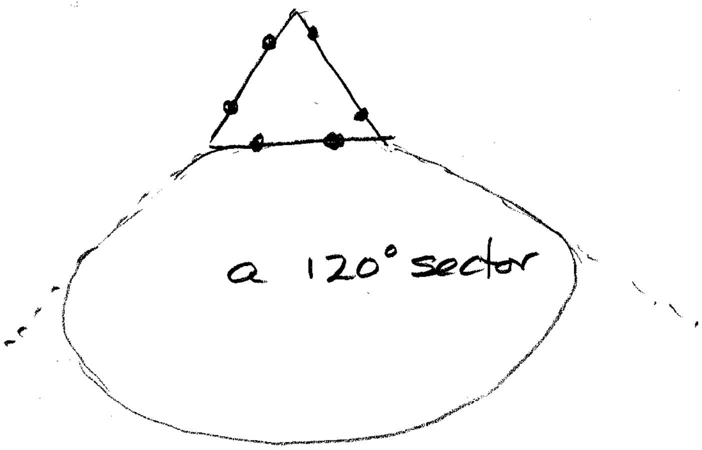
- Why not at a base station?

  - Base stations are located for few local scatterers, so no fast decorrelation
  - But if antennas are separated by 10λ to 20λ, there is usually just enough parallax to give a different resultant.

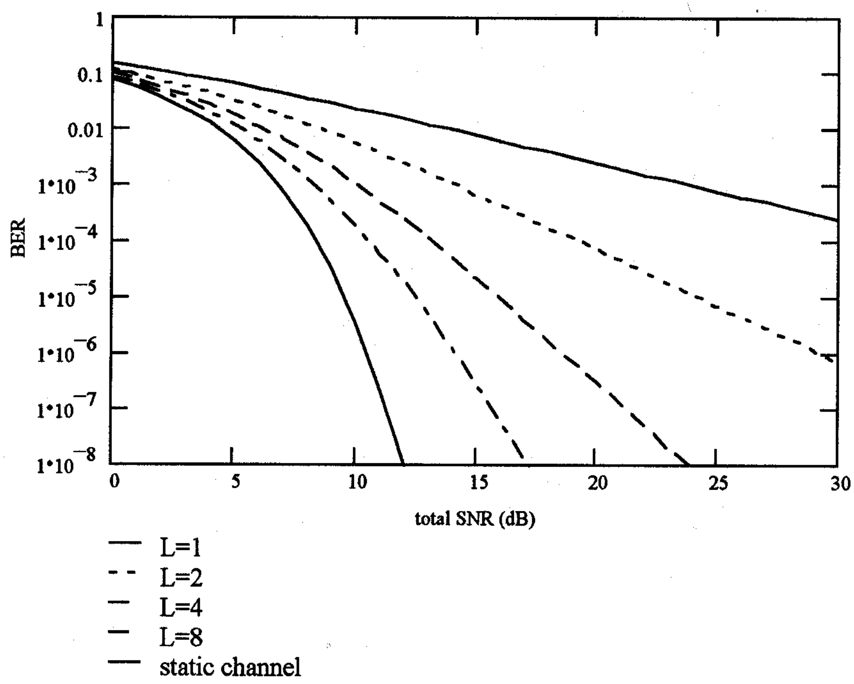
– And use of "dual diversity" at base stations is ubiquitous



from above



- If the probability of one antenna falling into a deep fade is p, then the probability of both fading is p^2



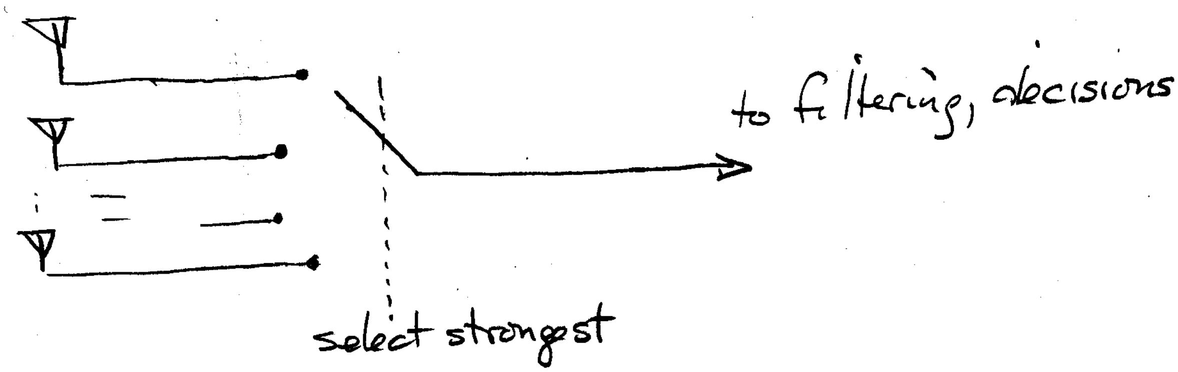
Max Ratio BPSK, Split Power

Diversity brings enormous improvement to error performance

and it is a major consideration in effective system design.

- How to make use of independently fading antennas?

  - selection diversity

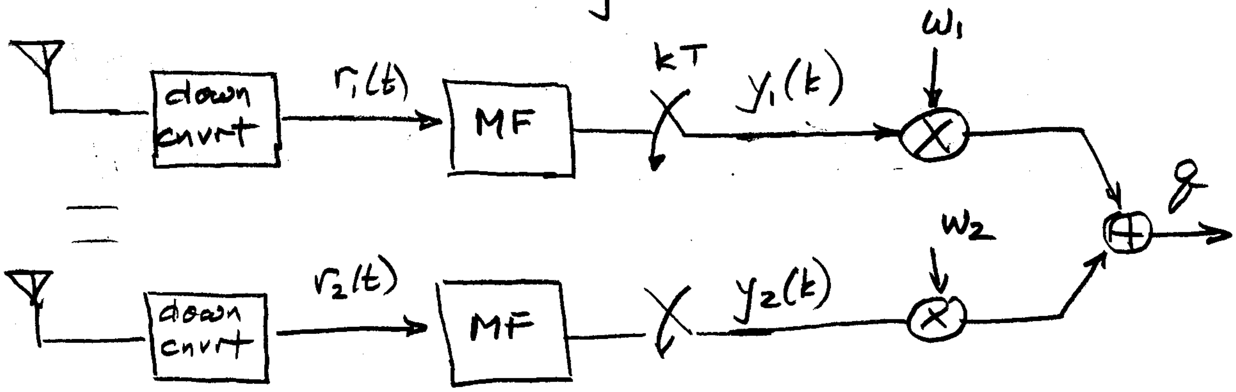


pros - simple
- don't need a whole receive chain for each branch if switch is located ahead of complex envelope recovery, MF etc

con: - throw away useful signal energy on unused branches

- phase hit on every switch, causes errors

— maximal ratio combining:



The received signals are

$$y_1 = g_1 \sqrt{2E_s}\, a + \nu_1$$

$$\vdots$$

$$y_L = g_L \sqrt{2E_s}\, a + \nu_L$$

If we could track the channels, so we have values of $g_1 \cdots g_L$ available, how would we choose weights?

$$w_1 = g_1^* \quad w_2 = g_2^* \qquad w_L = g_L^*$$

$$g = g_1^* y_1 + g_2^* y_2 \cdots + g_L^* y_L$$

$$= \left(|g_1|^2 + |g_2|^2 + \cdots |g_L|^2\right)\sqrt{2E_s}\, a + \underbrace{\left(g_1^*\nu_1 + g_2^*\nu_2 + \cdots + g_L^*\nu_L\right)}_{\nu}$$

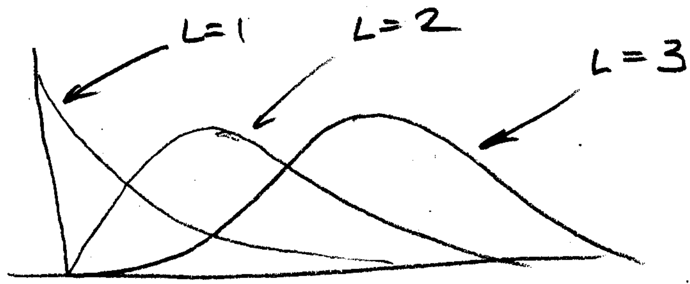
Get additional SNR per branch,
plus <u>coherent</u> averaging of power (diversity)
so deep fade is less lik

In MRC, we get

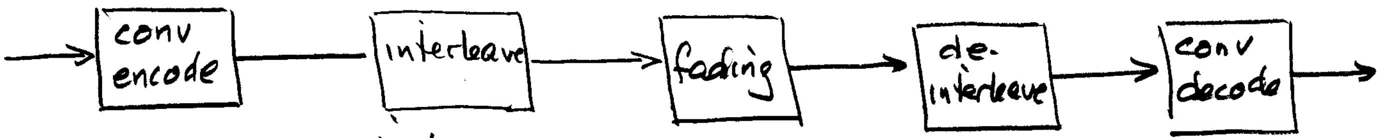
- additional SNR per branch
- coherent addition of signals (diversity)
- averaging of powers, so deep fade is less likely.

In detail, $z_i = |g_i|^2$, i.i.d

- z is exponentially distrib e^{-z}
- $z_1 + z_2$ is $z e^{-z}$
- etc

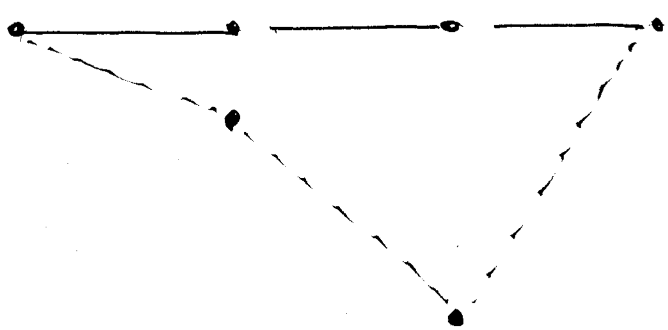


- Another form of diversity is time diversity, particularly when used with coding.



interleaver spans a couple of fades

Consider an error event, n coded bits each branch



- without interleaving, all bits in the event could fade together, prob of event $\sim 1/\Gamma$
- with interleaving, the coded bits in the event fade independently, prob that $\frac{d_{free}+1}{2}$ bits are faded $\sim 1/\Gamma^{(d_{free}+1)/2}$ (hard decisions)

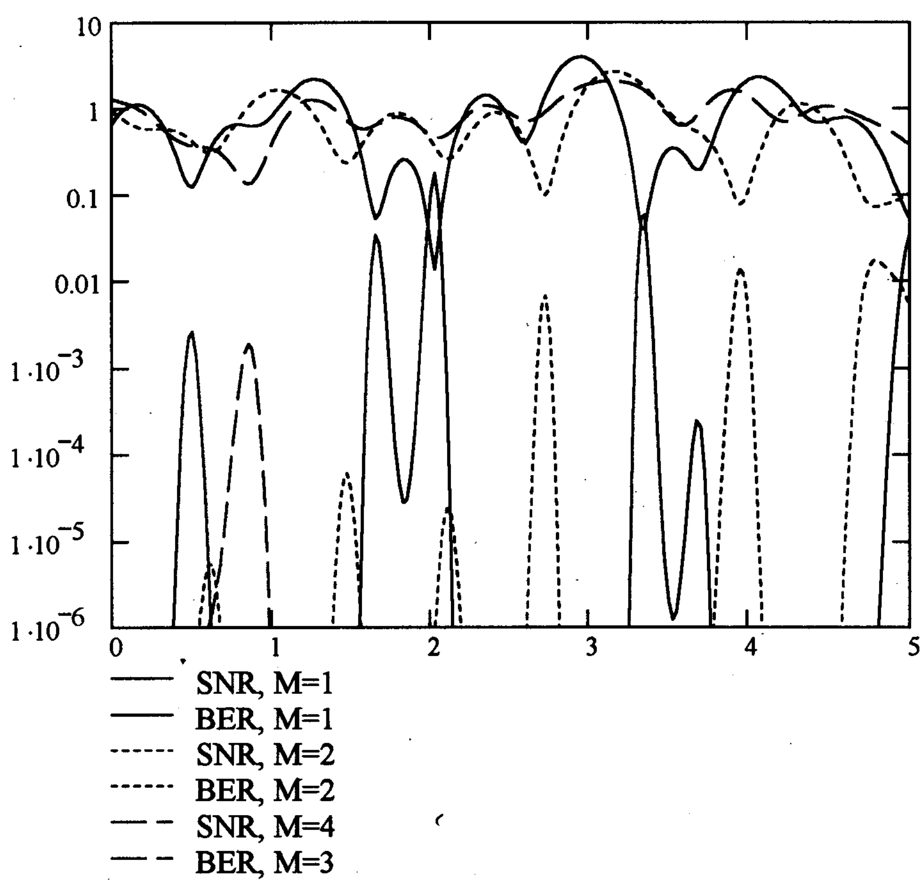
with soft decisions

$\Gamma^{-d_{free}}$

- Note that, even without diversity considerations, multiple antennas have independent noises, hence opportunity for averaging (i.e. picking up more signal energy). If all gains are equal, then Γ is improved by a factor M, or $10 \log M$ dB.

~~Our normalization $\sum_\ell \sigma_\ell^2 = \frac{1}{2}$ tends to conceal this.~~ (~~we use "received SNR"~~)

- Diversity combination tends to smooth the SNR variation, so fewer deep nulls, and reduce the average BER



all for $\Gamma_b = 15$ dB