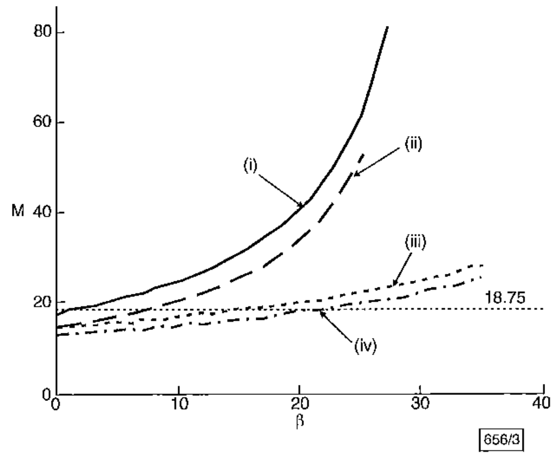

Fig. 3 *Gain M against phaseshift angle β, for various loads*

(i) $Q = 2Q_{base}, f_{ns} = f_{ns\,base}$
(ii) $Q = Q_{base}, f_{ns} = f_{ns\,base}$
(iii) $Q = 2Q_{base}, f_{ns} = 0.5f_{ns\,base}$
(iv) $Q = Q_{base}, f_{ns} = 0.5f_{ns\,base}$

FB-ZCS features and design considerations: Based on the above analysis, the features of the proposed converter can be summarised as follows: (i) The active switches operate with ZCS by phaseshift control and switch conduction overlap. Output rectifier diodes commute with zero-voltage switching (ZVS) and ZCS; (ii) The converter can operate with a fixed switching frequency using phase-shift PWM control techniques; (iii) Although ZCS is achieved, the topology still maintains a wide load regulation unlike other soft-switching topologies; (iv) Transformer and device parasitics can be fully utilised to achieve ZCS.

(*a*) *Switch overlap*: ZCS operations require the overlap time to be longer than a minimum value. Further normal operation sets an upper limit on this time. These constraints are given by eqn. 5:

$$\begin{aligned} t_{overlap} &\geq \left\{(t_1 - t_0)_{max}, (t_3 - t_2)_{max}\right\}_{max} \\ t_{overlap} &\leq (t_3 - t_2) + \frac{nV_oC_r}{I_{in}}\cos(\gamma) \end{aligned} \qquad (5)$$

(*b*) *Component selection*: While selecting resonant tank components, the parasitic parameters of the transformer must be considered. ZCS operation is obtained by lateral current commutation between S1\S2 (resonant) and S3\S4 (linear). Note that the resonant parameters are directly related to ZCS operation. From the waveforms of Fig. 2, note that in order for ZCS to be achieved, the energy stored in C_r must be sufficient to drive i_{Lr} to $-i_{in}$. This can be is shown as eqn. 6:

$$\frac{1}{2} \cdot C_r \cdot (n \cdot V_o)^2 \geq L_r \cdot (-I_{in\,max})^2 \qquad (6)$$

Conclusions: In this Letter we have presented a steady-state study of an FB-ZCS PWM converter used in a high-power, high-voltage DC application. The analysis results show the feasibility of the proposed topology in a high-voltage DC application. The FB-ZCS PWM converter has particular merits, such as fixed frequency operation and the ability to incorporate parasitic parameters.

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Capacities of multi-element transmit and receive antennas: Correlations and keyholes

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Multi-element system capacities are usually thought of as limited only by correlations between elements. It is shown that degenerate channels, called 'keyholes', may arise under realistic assumptions which have zero correlation between the entries of the channel matrix **H** and yet only a single degree of freedom.

Introduction: Bell-labs layered space-time (BLAST) is a communication technique for achieving very high spectral efficiencies in highly scattering environments using multiple transmit and receive antennas [1, 2]. These high spectral efficiencies are enabled by the fact that a scattering environment makes the signal from every individual transmitter appear highly uncorrelated at each of the receive antennas. As a result, the signal corresponding to every transmitter has a distinct spatial signature at the receiver. These different spatial signatures allow the receiver to effectively separate, with adequate signal processing, the transmissions, simultaneously and at the same frequency, by the different transmit antennas. In a sense, the scattering environment acts like a very large aperture that makes it possible for the receiver to resolve the individual transmitters.

The high spectral efficiency is reduced if the signals arriving at the receivers are correlated. A narrowband channel may be described in terms of a complex channel transfer matrix **H**, the entry h_{ij} of which corresponds to the response of the *i*th receiver to the signal sent by the *j*th transmitter. When the entries of **H** are distributed as complex Gaussians, maximum capacity is achieved when $\langle h_{ij}h_{kl}^*\rangle = 0$ for $i \neq k$ and $j \neq l$. Correlation between antennas may be reduced in actual deployments by, for example, separating the antennas spatially [3]. However, it may be shown that low correlation is not a guarantee of high capacity.

Singular value decomposition: In general, for *M* transmitters and *N* receivers, the $N \times M$ channel matrix **H** may be represented in terms of the singular value decomposition (SVD) [4]: $\mathbf{H} = \mathbf{U\Lambda V}^*$, where **U** and $\mathbf{V}^*$ are unitary matrices, with sizes $N \times N$ and $M \times M$, respectively, and $\mathbf{\Lambda}$ is an $N \times M$ diagonal matrix. Equivalently, the channel matrix **H** may be represented in terms of a sum of dyads: $\mathbf{H} = \Sigma_i^{\min(N,M)}\mathbf{u}_i\lambda_i\mathbf{v}_i^*$ where $\mathbf{u}_i$ and $\mathbf{v}_i$ are the *i*th row and column of **U** and $\mathbf{V}^*$, respectively, and * indicates a conjugate transpose. The singular value λ_i is proportional to the square root of the propagation loss. Each such dyad represents a mode of communication, or a degree of freedom. The form is suggestive of the sort of processing that we might want to do at the receiver and at the transmitter so as to maximise the communication rate, e.g. waterpouring [5, 6].

Keyhole: Picture, for example, two-element transmitting and receiving arrays surrounded by clutter. Ordinarily, this would lead to an uncorrelated Gaussian channel, which has been shown to have high capacity. Now, imagine placing a screen with a small keyhole punched through it, separating the regions containing the receiving and transmitting arrays. The only way for the radiowave to propagate to the receiver is to pass through the keyhole. The electric field incident on the keyhole is

$$E_{inc} = \begin{pmatrix} a_1 & a_2 \end{pmatrix}\begin{pmatrix} s_1 \\ s_2 \end{pmatrix}$$

where the channel coefficients a_1 and a_2 operate on the source signals s_1 and s_2. The channel coefficients include the effect of multiple scattering and, therefore, are assumed to be distributed as independent Gaussian random variables. The field transmitted through the keyhole is σE_{inc}, where σ is the scattering cross-section of the keyhole. The received field vector is

$$E_{rec} = \begin{pmatrix} b_1 \\ b_2 \end{pmatrix} \sigma E_{inc}$$

where b_1 and b_2 are complex Gaussian coefficients describing the scattering at the receive array. The channel matrix **H** is thus given by

$$\mathbf{H} = \begin{pmatrix} b_1 \\ b_2 \end{pmatrix} \sigma \begin{pmatrix} a_1 & a_2 \end{pmatrix} = \mathbf{b}\sigma\mathbf{a}^T = \sigma \begin{pmatrix} a_1 b_1 & a_2 b_1 \\ a_1 b_2 & a_2 b_2 \end{pmatrix}$$

which is clearly a dyad with one degree of freedom. As the coefficients a_1, a_2, b_1 and b_2 are independent, all entries of the channel matrix **H** are uncorrelated. Thus, the channel matrix has low correlation and yet a single degree of freedom. In contrast to the usual case, each entry of **H** is distributed not as a complex Gaussian but as a product of complex Gaussians. The probability distribution $f(p)$ of power p for such a process may be shown to be [7] $f(p) = (2/b^2)K_0(2\sqrt{p/b})$, where b is the average power and K_0 is the modified Bessel function.

In the above the concept of a 'spatial keyhole' was presented. Similar phenomena may be found in other bases. For example, Shiu *et al.* [3] has pointed out similar behaviour in the case of two rings of scatterers, at large separation. In that case, the single degree of freedom is supported by a 'spectral keyhole' (i.e. a single plane wave between the scattering regions). An example of a keyhole in a realistic environment is propagation in a hallway or a tunnel. At microwave frequencies the hallway may be thought of as an overmoded waveguide. The number of modes supported by a waveguide limits the maximum number of degrees of freedom. Correlation between antennas will reduce the capacity further. In the presence of loss, the lowest order mode dominates at large distances from the source. The channel thus has only a single degree of freedom, represented by the lowest order mode, a 'modal keyhole'.

In outdoor environments, the receiver is often obstructed from the transmitter by a diffracting edge, such as a roof edge, or a building corner. If the dominant path from the transmitter to the receiver is via diffraction at the roof edge, the edge acts as an equivalent horizontal line source with varying current strength along its length. If the base antennas are vertically separated, the richness of the perceived channel is collapsed, and a 'keyhole' is formed. Increasing the vertical separation would not be of any use. This may be remedied by placing the base antennas in a horizontal array. In that case, adequate antenna separation will be required to assure low correlation [4].

Conclusion: We have shown that degenerate channels, called 'keyholes', may arise under realistic assumptions which have zero correlation between the entries of the channel matrix **H** and yet only a single degree of freedom.

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Impedance characteristics of planar bow-tie-like monopole antennas

Zhi Ning Chen

The impedance characteristics of planar bow-tie-like monopole antennas have been studied experimentally. The planar bow-tie-like monopole antenna achieves a broad bandwidth, typically of >75%. A modified formula is suggested to accurately evaluate the frequency corresponding to the lower edge of the impedance bandwidth.

Introduction: Planar monopole antennas are interesting due to their broad impedance bandwidth and simple planar structure, where a thin planar element can be readily employed as a radiator instead of the wire element of a traditional monopole antenna. A typical circular planar monopole with a 1:8 bandwidth was presented in [1]. Planar monopole antennas with various planar elements, such as elliptical (circular), rectangular (square), and trapezoidal plates, have also been proposed and investigated experimentally and numerically [2, 3]. Formulas have been used to evaluate the frequency corresponding to the lower edge of the impedance bandwidth (FLEIBW) [4]. The impedance characteristics of planar circular monopole antennas have been analysed by the method of moments with a wire grid and triangular cell meshing [5, 6].

In this Letter, planar bow-tie-like (BTL) monopole antennas are presented and experimental investigations on their impedance characteristics carried out. A typical broad impedance bandwidth of 75% is realised. A modified formula is suggested for the accurate evaluation of the FLEIBW of planar BTL monopole antennas.

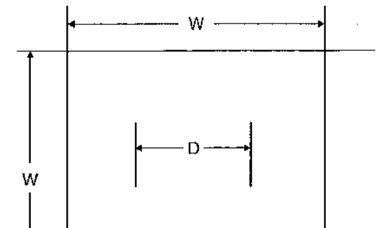

Fig. 1 *Geometry of proposed planar bow-tie-like monopole antenna*

Measurements and results: The geometry of the proposed planar BTL monopole antenna is shown Fig. 1. A 0.5mm thick BTL brass plate was located vertically above the ground, operating as a radiator element. A 50Ω coaxial probe fed the BTL plate at the midpoint of its bottom side through an SMA connector. The probe had a diameter of 1.2mm. The gaps between the ground plane and the bottom side were d = 0.8mm, 1.6mm and 2.4mm. The BTL plate was considered as a square plate measuring $W \times W$ = 40 × 40mm² with two identical trapezoidal notches. The distance between the top points of the trapezoidal notches was D. We