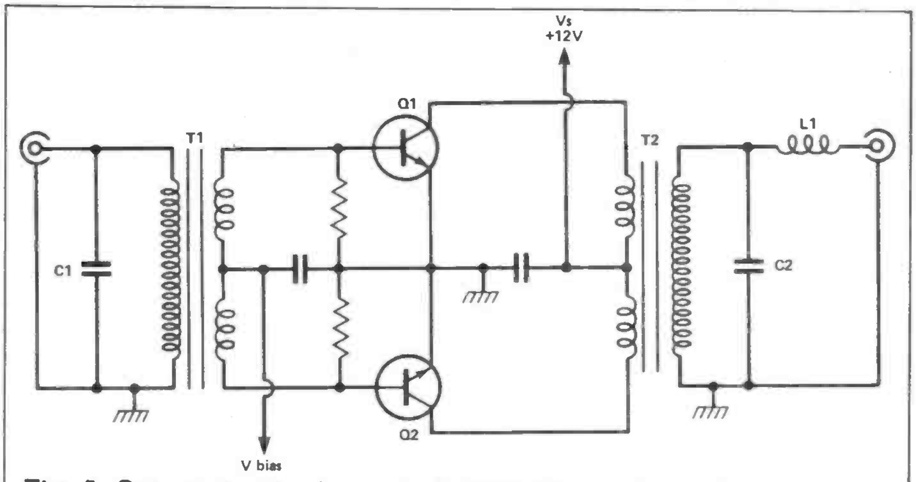

Fig. 5. Output circuit of a typical 100W HF transistor PA

when I saw high power transistor circuits with extra capacitance added in parallel with the windings. It struck me as very odd indeed.

Figure 5 is just such a circuit example. It depicts the standard 12V 100W broadband HF PA stage using stacked ferrite rings as the basis for the input and output transformers. The transistor input and output resistances are very similar at this level of power and supply voltage. Without going into too many details, please accept as fact that the ratio between primary and secondary on T1 should be 4:1, and 1:4 on T2. Why is Cl across the primary of T1 (typical value 150pF) and C2/L2 across T2 (typical values 220pF, 100nH)?

The answer is leakage inductance. If T1 and T2 were perfect transformers, the extra components would not be necessary. In the real world, the total flux induced by the primary circuit does not completely encompass the secondary winding with the result that some of this magnetic path 'gets lost'. This is like adding a low value inductance in series with both the primary and secondary windings. This has all sorts of implications.

High power

In high impedance circuits, such as the preamp of **Fig. 3**, leakage inductance doesn't matter too much. As I said earlier, the most that it will normally do is to cause a ripple in the frequency response. With a typical value of a few nanohenries for a small transformer, this series reactance is very low compared with the load impedance, even at the highest operating frequency. In the circuit example of **Fig. 5** the load impedances are in the region of a couple of ohms at most. It only takes a touch of stray inductance to insert unacceptably high reactances in series with the load. The effect of these is to reduce the current swing available in the RF signal. In uncompensated circuits, the high frequency falloff in output power (and gain) is very marked. A design which delivers 100W at 3.5MHz may only give around 40W at 29MHz. Similarly, the available gain may fall from 20dB to 8dB or less. Unfortunately, the falloff due to leakage inductance in the transformers looks almost identical to the rolloff curve of poor quality PA transistors. It is no wonder that many people are left scratching their heads about disappointing performance.

The answer lies in the arrangements shown in **Figs. 6** and **7**. You can't design a broadband transformer which doesn't have leakage inductance. You have to find a way of living with it. Like all these things, there is almost a conspiracy against the RF designer. To build powerful amplifiers you must use components, ie. ferrite transformers, which are man enough to handle the expected power. This means that they must be large. The larger they are, the more leakage inductance they must exhibit therefore the worse the problem is. You have to treat the leakage inductance as if it was a separate component. In **Fig. 6**, a schematic representation of the input circuitry, the stary inductance is resonated with the capacitor C1. In theory, C1 could be connected in series with the primary to form a series resonant circuit. However, this would provide cancellation at one frequency only. Connecting C1 as shown produces a less complete, but adequate cancellation over a much wider frequency range. On the LF side, C1 has a high reactance and T1 performs its job in the normal manner. As C1 starts to resonate with the leakage inductance towards the HF end, the impedance at the input rises although not excessively because the Q is low. The equivalent of 2:1 SWRs can easily be tolerated at the input which is the sort of value that might be expected across the range 1 to 30MHz. A more complete conpensation is required on the output transformer.

The output circuit

Figure 7 shows the schematic details. If a transistor output stage is to deliver a specified output power over the HF spectrum, the load resistance which the devices actually see needs to be kept to within around 10 per cent variation on the mean value. In this case, leakage inductance is accomodated by making it part of a T filter arrangement with a rolloff designed for just above the operating range. The stray inductance provides one arm and L1 provides the other. C2 acts as the bottom of the T. In practice the only way to find a value for L1 and C2 is empirically. There are people who say that this type of network can be calculated but, frankly, I don't believe it. In a 100W design, insert about 80nH for L1 and around 100pF for C2 as ballpark values. Chop and change until you obtain the most level response. The precise values will depend completely on the characteristics of the transformer, so that should be designed first. (I suppose that goes without saying.)

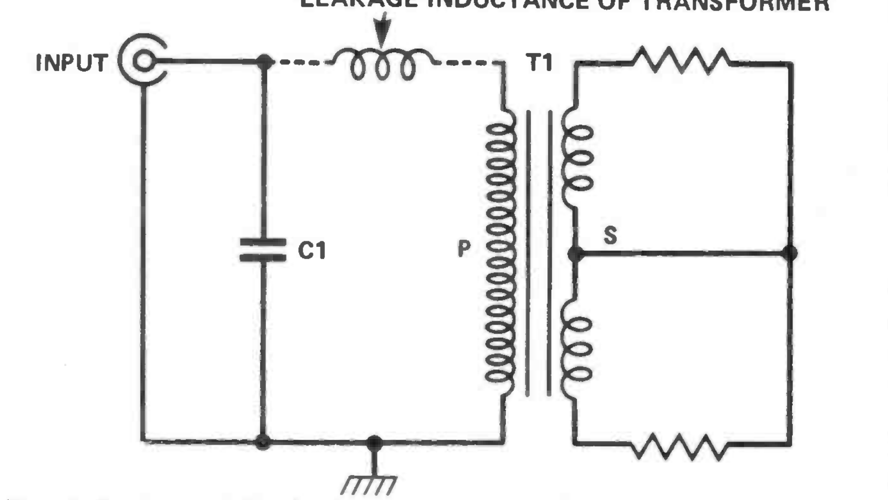

Fig. 6. Tuning out the leakage inductance. Capacitor Cl is chosen to resonate with the leakage inductance at the highest frequency which the transformer is required to match.