Technicalities

Broadband transformer design by Frank Ogden G4JST, Editor Ham Radio Today

Ferrite based transformers offer one of the most powerful design tools available to the radio amateur. They can both isolate and match lumps of circuitry over the complete HF spectrum with virtually no loss. It is almost unthinkable to build a piece of gear without using them in some form or other so I make no apologies for presenting them in the *Technicalities* column.

Although RF transformers are manufactured from ferrite or dust iron cores, they use exactly the same principles as transformers operating at any other frequency. A current flowing in the primary coil induces a magnetic flux in the core. A second coil intercepting this flux, ie. wound on top of the first one, produces a voltage proportional to the applied AC voltage and the ratio of the turns between the two coils.

As with 50Hz mains transformers, there are limits. The primary represents an inductance in parallel with the applied voltage. If the inductance is too low, the circulating current will cause such intense magnetisation of the core that it will saturate it, and the losses will increase dramatically. Many people will have heard and smelt the distress of a mains transformer inadvertently connected to its 115V tapping. RF transformers can saturate in precisely the same way, but more about this later.

Small signal, wide bandwidth

Regardless of the operating frequency or core material, the transformer law, as shown in **Fig. 1** applies. The turns ratio (between primary and secondary) is the square root of the impedance ratio. Put another way, the impedance ratio is the square of the turns ratio. If you wind nine turns on a ferrite bead (excellent for small RF transformers) and then a further winding of three turns, a load of 50 ohms attached to the three turn winding will be transformed to a 450 ohm load as seen across the terminals of the nine turn winding. For those with a practical view, three turns on a ferrite bead in parallel with a 50 ohm source will handle up to about 100mW of power — transformed to an impedance dictated by the number of secondary turns — across the range 2 to 70MHz. Precise characteristics though will depend on the ferrite material from which the bead was made. An alternative statement of transformer law is shown in **Fig. 2.**

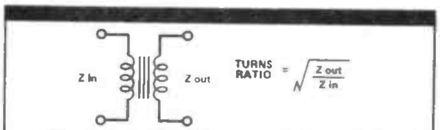

Fig. 1. The turns ratio is the square root of the impedance ratio.

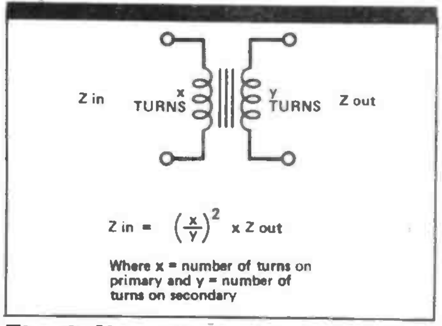

Fig. 2. If you know the turns ratio of a transformer and the impedance connected to one side of it, you can calculate the impedance 'seen' at the other side of the transformer.

Figure 3 offers a very practical application of simple wideband transformer design. This grounded gate JFET preamp provides about 14dB of very low noise gain right across the range 1 to 30MHz. Above 30MHz, there is a gentle falloff in gain; the unity figure is reached around 100MHz. Strangely, the gain slope has almost nothing to do with the ferrite transformer and everything to do about circuit parasitics. The transformer is shown wound with a ratio of 5:1. This transforms the 50 ohm output load to 1250 ohms at the JFET drain. The device output capacitance is about 5pF. The upper computer graph shows the predicted response due to the loading effect of 5pF across 1250 ohms. The real plot would show slight ripple due to the leakage inductance of the transformer resonating with this capacitance.

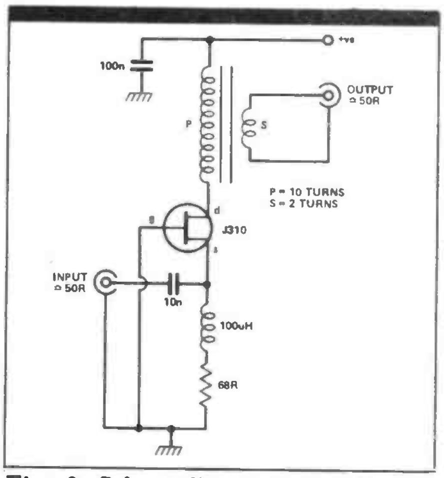

Fig. 3. A broadband low noise RF pre-amp

The effect of capacity loading in small signal broadband transformers is clearly shown in the second plot. The turns ratio has been increased to 10:1. Although the circuit gain now rises to 20dB, the frequency rolloff is much more marked. In this, there is a profound truth for the circuit designer: the bandwidth of a circuit is inversely proportional to its gain. The parasitic components which determine the gain of the circuit shown in **Fig. 3** are brought out in **Fig. 4.** The sample holds one more lesson which is directly related to the ferrite material. The transformed load resistance, Rp if **Fig. 4,** is directly in parallel with the primary inductance of the transformer. The lowest operating frequency will be determined when the inductive reactance of the primary winding has the same value as the transformed load resistance. Since the transformer primary inductance will be a function of the core material, the LF frequency response is totally dependent on the grade of material used in the core. Furthermore, the core is most likely to saturate at the bottom end of the range.

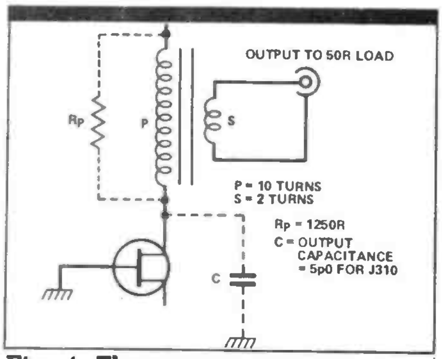

Fig. 4. The unseen components of Fig. 3. It is these, and not the characteristics of the ferrite which largely determine the frequency response of a broadband circuit.

Leakage inductance

The earlier circuit example showed that high impedance, transformer coupled broadband circuits exhibited a bandwidth determined mostly by external loading capacitance. It therefore came as quite a shock to me