In Practice

Top ten misleading terms

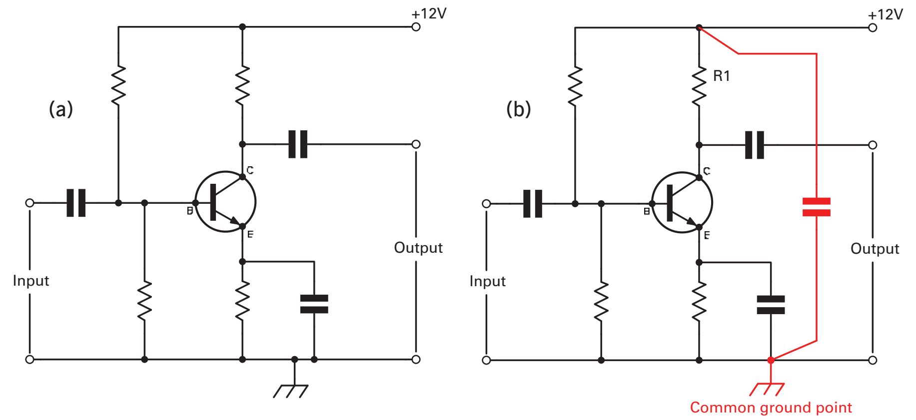

FIGURE 1: (a) This circuit is incomplete. (b) This capacitor is always needed.

CONFUSED? YOU WILL BE. RF engineering has a specialised language that newcomers have to learn. But the more experienced we become, the more we tend to forget how self-contradictory some of that language is. Here are RF engineering's Top Ten Terms that can confuse anyone who doesn't already have a firm grip on their true technical meaning, and can trap even the most experienced. There isn't space to examine all of them in detail; the main purpose of this article is to help you to be on your guard.

CW. Let's start with an easy one, a very old jargon term that has simply changed its meaning. The exact meaning can only be determined from context, but everyone knows that it usually *doesn't* mean 'Continuous Wave'.

DC. The original meaning of 'Direct Current' was quite narrowly defined: a current that is always flowing in the same direction – the simple opposite of Alternating Current. However, 'DC' is often used very differently to imply that a current or *voltage* is not only unidirectional but also *constant in value*. That usually implies that that the entire circuit is in a steady, unchanging state and that any variations such as drift, hum and noise are being deliberately ignored.

We also speak of 'DC bias' or 'DC conditions' when discussing circuits that are also handling AC signals (including RF). The hidden assumption is that DC conditions and AC signals truly can be separated and analysed in two different ways. But the real-life circuit knows nothing of this – it only responds to the *instantaneous total* voltages and currents in every part of itself. If you intend to analyse the DC conditions and AC signals separately, it is also your responsibility to check that they don't interact significantly… and that can develop into a very long story.

When people use 'DC' in a casual, everyday fashion, they often aren't aware of all those underlying assumptions. You can never be certain how much they really mean to imply, or how much of that is really true.

12V DC. This term can sometimes involve some strange values of '12'! Many so-called '12V' transceivers are actually intended for a 13.8V supply, the nominal voltage of a car battery under full charge. For the same reason, regulated mains power supplies for transceivers are often set to provide 13.8V rather than 12.0V. A label saying '12V DC' can also hide a host of problems including poor voltage regulation, 100Hz ripple, 50Hz hum, voltage spikes, dropouts and noise.

These problems are at their worst in small unregulated power supplies such as plug-in 'wall warts'. These units often include nothing more than a small under-specified mains transformer, some rectifier diodes and an overworked electrolytic smoothing capacitor. Everything is chosen mostly for small size and cheapness rather than electrical performance. With very light loading (low output currents) the output voltage from such a supply can easily exceed 15-16V, which may cause damage to some circuits. At high output currents, the voltage will fall far below 12V, and will become dominated by 100Hz AC ripple.

Small switch-mode supplies are usually distinguishable by weight because they don't have a 50Hz mains transformer; well designed units will be electronically regulated and even some tiny plug-top supplies can perform very well indeed. But as the 'EMC' column has shown, there is a growing problem with illegal imports that don't have any filter components.

VISUAL VAGUENESS. Confusing language is not confined to words. In exactly the same way that 'the map is not the territory', a circuit diagram is a very incomplete description of the hardware that it represents. Essential parts of the circuit are routinely left out and the stylised drawings are routinely misleading about important layout details. So whenever you read a circuit diagram, remember all *the* time that the *diagram is not the hardware*.

For example, at first glance **Figure 1a** looks reasonable enough: a common-emitter transistor amplifier with its DC biasing resistors and a decoupling capacitor from emitter to ground. But this circuit has a vital component missing. It simply won't work – not literally as drawn. **Figure 1b** shows the missing component: the decoupling capacitor from the top of the output load resistor R1 to the common signal 'ground'. Every individual stage in an AC/RF amplifier circuit requires its own decoupling capacitor; without it, the output circuit is incomplete because there isn't a closed loop at signal frequency. Supply rail decoupling can be a tricky subject and these components should never be taken for granted or left out. Another misleading feature of normal circuit diagrams is that decoupling capacitors are brought neatly down to separate points along the common ground rail (and there's another misleading term; see later). Figure 1b shows exactly where the decoupling capacitor should be connected, as close as physically possible to the common signal ground point, which in this circuit is the bottom end of the emitter decoupling capacitor.

PEAK ENVELOPE POWER. Returning to the written word, the formal definition of PEP is on page 22 of your licence: the average power supplied by the transmitter during one radio frequency cycle at the crest of the modulation envelope. It isn't an easy concept to understand (the definition itself conceals a number of hidden assumptions) but the worst obstruction is the confusing name, 'Peak Envelope Power'. This is simply bad English, three words thrown together in the same careless way as 'telescoping tower owners'. Only a committee of engineers could have achieved this.

EFFECTIVE RADIATED POWER. 'Effective' is a word that can have two very different meanings. One of them is simple and straightforward; the other is less frequently heard but means almost the exact opposite! True to form, the 'E' in ERP has the second meaning. Whenever someone says, 'That's *effectively true*', we rightly suspect that we aren't being told the whole truth. In scientific usage, it implies something that

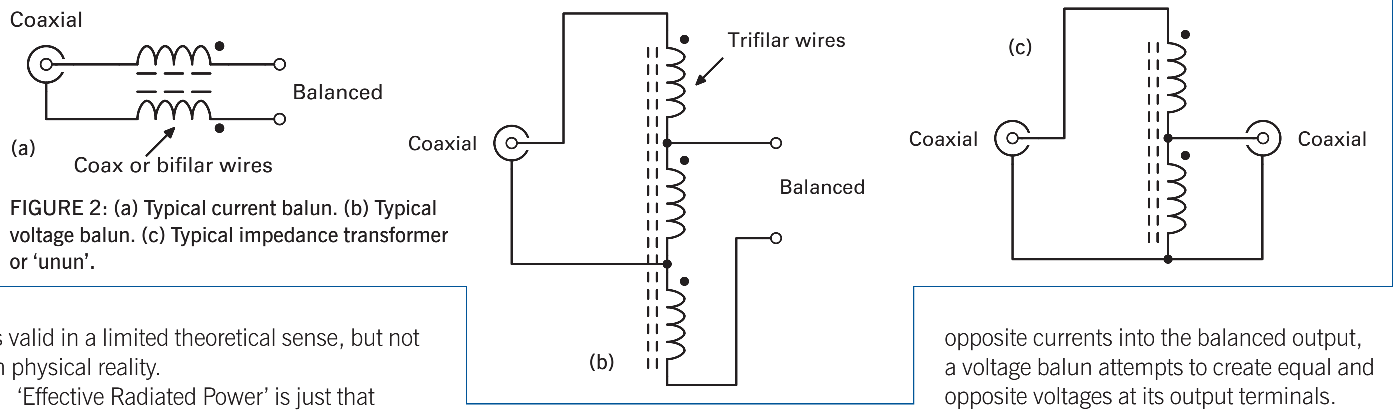

FIGURE 2: (a) Typical current balun. (b) Typical voltage balun. (c) Typical impedance transformer or 'unun'.

is valid in a limited theoretical sense, but not in physical reality.

'Effective Radiated Power' is just that type of concept – it is valid for the assessment of signal levels and interference at distant receiving sites; but ERP usually *does not* mean the amount of RF power that is being physically radiated. ERP is not a reliable concept for any assessment at a transmitting station itself, where details of the actual power level and antenna radiation pattern become all-important.

VSWR. We have all been taught about standing waves on a mismatched transmission line. If we seek out a voltage maximum, somewhere along the line, then a quarter-wavelength away we'll find a voltage minimum. The Voltage Standing Wave Ratio is the ratio between those maximum and minimum voltages. Simple enough, it's in all the textbooks… but wait a moment. That measurement obviously requires access to a number of points along the line, some appreciable distance apart. But in practice we measure VSWR by inserting a meter at a single point on the line – so how can that be possible? And how can components that are too small to contain a standing wave even *have* a VSWR?

The answer is that 'VSWR' has two parallel but separate meanings. The classical meaning relates to standing waves on a length of transmission line as described above; but this is also the least common meaning. The quantity that we most often call 'VSWR' is an entirely theoretical construct, a *mathematical equivalent value* which has been calculated from a real-life measurement of something else – impedance, reflection coefficient or return loss. All of these can be measured at a single point, and are referenced to a completely arbitrary value of system reference impedance, most commonly 50Ω. The only meeting between the two different meanings of 'VSWR' is in the land of theory, in special cases involving a lossless 50Ω transmission line.

BALANCED FEEDLINE. A truly balanced feedline is a physically symmetrical twin feeder or parallel line whose two conductors are carrying exactly equal and opposite RF currents. The myth is that parallel line is somehow self-balancing due to mutual coupling between the two wires. This coupling does exist, but it is easily overwhelmed by other effects that force the line to carry unwanted common-mode currents (in the same direction on both wires). In any practical antenna layout involving twin feeder, significant levels of common-mode current are likely to be present unless some definite action has been taken to prevent it. Therefore it's impossible to *buy* balanced feedline off the reel – so if you see those words on the label, ask who balanced it! And that leads us immediately to the next misleading word…

BALUN is an abbreviation for 'balanced to unbalanced transformer' – but sometimes hardly one word of that is true. Part of the confusion is because there are two fundamentally different types of balun, and one of them has at least three other names as well. **Figure 2a** is called a *current balun*; it works by preventing common-mode current from flowing on the outside of the coaxial feedline, which in turn forces the currents fed into the two legs of the antenna to be equal and opposite (or much more so than they would be if the balun wasn't there). However, it's equally valid to think of this device as an RF choke to block the unwanted common-mode currents, so alternative names for exactly the same device are a choke balun, feedline choke or line isolator. The main difference is in the physical packaging, eg a current balun for use with an antenna will probably have screw terminals on one side and a coax connector on the other; but exactly the same device could also be packaged with two coax connectors for use as a line isolator (probably further down the feedline towards the shack).

To avoid confusion, it's best to limit the word 'balun' to applications at the antenna itself, or when the device is connected to a length of twin feeder. But if the same device is being used only as a feedline choke, entirely in coax and with no balancing function involved, then call it a 'choke'.

Figure 2b was the original type of 'balun transformer' but is now more properly called a *voltage balun*. This circuit (with its several variations) is a true transformer, an auto-transformer with tapped windings. Unlike a current balun which drives equal and opposite currents into the balanced output, a voltage balun attempts to create equal and opposite voltages at its output terminals. Unfortunately, a closer examination of what happens with an unbalanced load reveals that equal voltages can only be achieved driving common-mode current out of the secondary centre tap and onto the feedline – exactly the opposite of what we want a balun to do! Voltage baluns do have their place, but that place is almost always on a circuit board, eg in push-pull amplifiers. For antenna applications, voltage baluns are almost always the wrong choice.

Figure 2c is something else again, an impedance transformer which is unbalanced at both input and output. It's categorically wrong to call this a balun because there is no balancing function at all. The term 'unun' (unbalanced to unbalanced transformer) has been coined to describe this type of circuit but it's better to call it exactly what it is – simply an impedance transformer.

And the undisputed Number One Misleading Term is…

GROUND. This is a mythical place to which all circuit returns can be connected… and forgotten. The myth is that every connection marked 'ground', no matter where it may be located, is at something called 'ground potential', which is assumed to be the same everywhere. That simply isn't true! The best we can hope for is a 'common' connection between parts of a circuit that are physically close together. Not far away, another common connection point may be at quite a different potential – different enough to cause huge amounts of trouble.

British engineers tend to say 'earth' where the Americans say 'ground', but life becomes much clearer if we use those two words to mean something different. Use 'ground' to mean a local common connection point, which can be anywhere at all (eg on a circuit board). Reserve the word 'earth' for direct electrical connections to the Mother Planet. In particular, avoid the term 'RF earth' unless you really do mean a short, direct connection to a spike driven into highly conductive earth. When the distance from that connection point is more than a small fraction of a wavelength, it ceases to be an effective earth connection for RF; and if you persist in calling it 'RF earth', you'll only be fooling yourself.