Transmitter Power Output Measurements.

Introduction

The Radio Amateur is limited to the transmitter power output as laid down in the BR68 *schedule*. Column 4 it gives the *Maximum power level (in dB relative to one Watt) PEP.* These terms will be explained in this lesson.

History

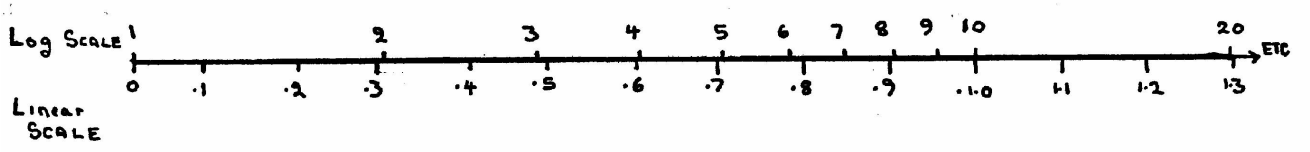
In the earlier days of Amateur Radio, meters to measure RF power were not generally available.
However, it was realised that you could not get more RF power from a valve (or transistor) stage than the DC power supplied to it. The *schedule* of those days therefore quoted the Maximum transmitted Power in terms of "DC input" to the final stage, for Amplitude Modulation. This could be simply measured by knowing the DC supply voltage and multiplying it by the Current flowing through the final valve (or transistor). It was then assumed that the efficiency of the final stage would not exceed, say, 50%. DC voltmeters and ammeters were part of the transmitter and mounted on its front panel. W= VxI As the supply voltage was normally constant the Maximum permitted power could be marked as the equivalent current on the ammeter.
Although this technique is now longer mentioned in the *Schedule*, this type of calculation often appears as a exam question as it is still in the syllabus.

Example
The final transistor in a 7 MHz transmitter has a collector current of 250 ma.
The voltage regulator supplies 30 Volts from a 50 volt source.
What is the DC input power to this stage?
The DC input is the product of the transistor voltage and current.
W= V x I = 0.25 x 30 = 7.5 Watts.

THE DECIBEL

The DECIBEL is used as a comparison. It can either be a comparison between two measurements **or** between one measurement and a standard unit.
(This unit of comparison , the BEL, was named after the inventor of the telephone, Alexander James Bell.
However, it was found that this unit was too large, so it was divided by ten .
Hence **deci Bel** and is usually abbreviated to 'dB'.

As you may know, the human ear operates in a *logarithmic* fashion.
The Decibel therefore follows a *logarithmic law.*
Below is a comparison between a *Log* and a *Linear* scale.



The use of the decibel as a comparison between two measurements.
For example, an amplifier with a signal of 1 Watt at its input gives an output of 2 Watts.

$$\text{Gain} = 10 \log \frac{\text{Output Power}}{\text{Input Power}} \text{ dB} = 10 \log \frac{2}{1} \text{ dB}$$

(The log of 2 is 0.3010)

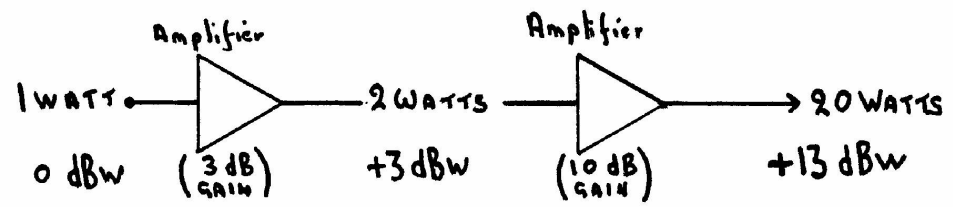
Gain = 10 x 0.3010 = 3.0 dB
Thus doubling the power is equivalent to an increase of 3dB
As another example, the output of the previous 3dB amplifier is connected to a second amplifier, raising the power to 20 Watts.

$$\text{Gain(of this second amplifier)} = 10 \log \frac{20}{2} = 10 \log 10$$

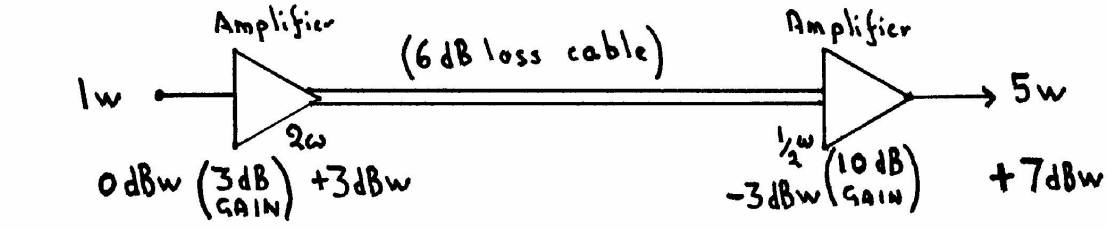
(The log of 10 is 1)

Gain (of this second amplifier) = 10 x 1 = 10dB
To find the gain of the two amplifiers together just add the two DB gains.

IE Gain of the first amplifier (from 1 Watt to 2 Watts) is	3.0 dB
Gain of the second amplifier (from 2 Watts to 20 Watts) is	10.0 dB
Thus the total gain is	13.0 dB



The decibel is used for losses as well as for gains.
For example, cable has losses. This means that power is lost. In other words, the power at the output of the cable is less than the power at the input of the cable. Common sense really!
If the cable connecting the amplifiers (in the example above) has a loss 6dB it will reduce the power from the amplifiers.



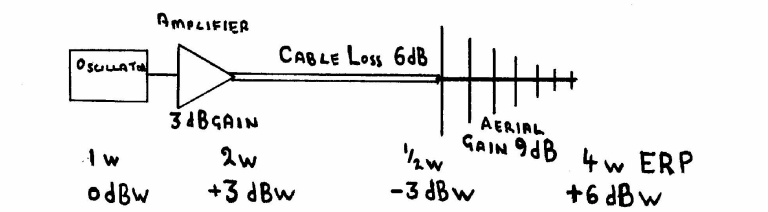
The total gain of the amplifiers is	13.0 dB
Subtract the loss of the cable	- 6.0 dB
Resultant overall gain is therefore	7.0 dB

Remember, a doubling of the power is the equivalent to a change of 3dB.
The 'reverse' is also true..... -3dB (spoken ' minus three dB') represents a halving of the power.

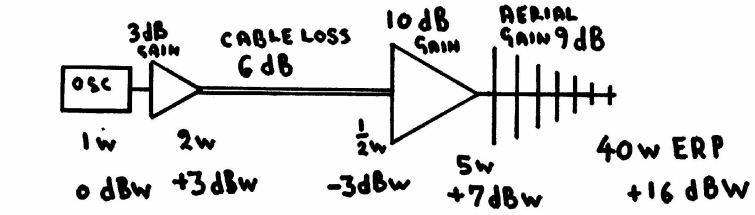
In the amplifier above, the theoretical output was 20 Watts. However, when the cable loss is taken into account, the output is 6dB less. This 6dB can be thought of as 'two lots of 3dB'.
Each of these 3dB results in a halving of the power.
Thus 3dB down on 20 Watts is 20 divided by 2 = 10 Watts
And 3dB down on this 10 Watts is 10 divided by 2 = 5 Watts

Adding the losses and gains

An advantage of using dB is that *losses* and *gains* can be simply added mathematically.
Example



The cable here is shown as having a *loss of 6dB.* It could also be said to have a *gain of –6dB.* Beware of this in RAE questions!
Now add a 10dB mast head amplifier, to the above example, and calculate the new figure for the **E**stimated **R**adiated **P**ower.
The use of the dB as a comparison between one measurement and a standard unit.
The output of radio transmitters is compared to the 'Watt'. 1 Watt = 0dBW



Note that '0 dBW' does **not** mean there is zero power.....
It means the power is exactly the same as the reference, 1 Watt, in this case.

Here are some examples of dBW values:

+3dBW is twice the reference .	IE 2 Watts
+6dBW (is 3dBW + 3dBW).	IE 4 Watts.
+9dBW (is 3dBW + 3dBW + 3dBW)	IE 8 Watts
+12dBW (is 3dBW + 3dBW + 3dBW + 3dBW)	IE 16 Watts
-3dBW is half the 1 Watt reference.	IE 0.5 Watts (or 500mW)
-6dBW (is -3dBW -3dBW)	IE 0.25 Watts (or 250mW)
-9dBW (is -3dBW -3dBW -3dBW)	IE 0.125 Watts(or 125mW)

The **+**dBW is a power *greater* than the reference.
The **-**dBW is a power *less* than the reference.

The reference, in this case, is the Watt but it does not have to be...
For small powers it is usual to use a reference power of 1mW (one thousandth of a Watt)
1mW is 0dBm
2mW is +3dBm etc..... So, look very carefully at the letter(s) following dB!

The decibel is not just used for *power* comparisons and measurements. For example, it can also be used for voltages and currents but there is a difference in the formula.

$$dBV = 20 \log \frac{\text{Output Voltage}}{\text{Input Voltage}}$$

$$dBI = 20 \log \frac{\text{Current output}}{\text{Current input}}$$

The formula uses '**20** log' etc . current whereas the power formula uses '**10** log'

dBV continued

Example.

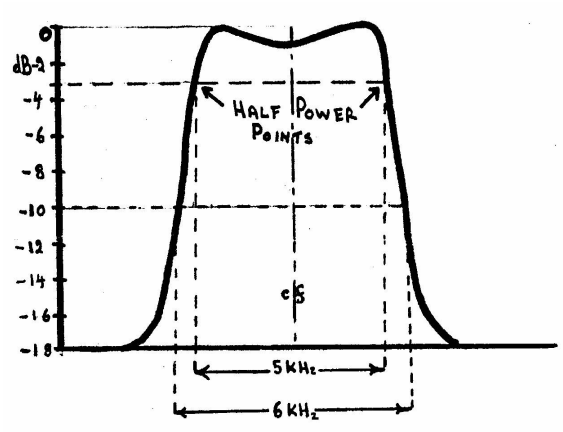
The voltage at the aerial input terminal of a receiver is 0.5μV. The manufacturers state that the minimum for good quality reception is 1μV. What is the gain (amplification) of the required amplifier?

The Voltage ratio is $\frac{1.0\mu V}{0.5\mu V} = 2.0$ Gain = 20 log 2
= 20 x 0.3010
= 6dB (to the nearest dB)

Response Curves

Decibels are often used as the scale for response measurements.
The response curve shown is typical of a *double tuned I.F.transformer.*
Bandwidth is usually quoted to be the frequencies between the *half-power points.* This is "3dB down".
The maximum of the response is taken as the reference (0dB).

Other bandwidths would actually quote the measuring level.
For example," the transformer has a 6kHz bandwidth to the 10dB points".



Watts to dBW conversions

The "rules" allow the power to be noted in the *station log* in either *Watts* or in *dBW.* However, the schedule gives the power in only "dBW". It is therefore necessary to be able to convert from one unit to the other.

Watts = 0.1 x antilog dBW and dBW = 10 x log Watts

Here are some useful conversions (to save you fighting with "logs" and "antiogs")

-20 dBW = 10mW	**10 dBW = 10 W**	**20 dBW = 100 W**	
0 dBW = 1 W	13 dBW = 20 W	**22 dBW = 160 W**	For the exam it is
3 dBW = 2 W	**14 dBW = 25 W**	**26 dBW = 400 W**	worth remembering
6 dBW = 4 W	**15 dBW = 32 W**	30 dBW = 1KW	the conversions
9 dBW = 8 W	**16 dBW = 40 W**	40 dBW = 10 KW	in **bold** type.

Here are some useful ratios….

Twice is 3dB	8 times is 9dB	100 times is 20dB
4 times is 6dB	10 times is 10dB	1000 times is 30dB

QUESTION D1
An Amateur Radio VHF transmitter has an out put of 10 Watts. It is connected to a Yagi aerial that has a gain of 6dB using an old piece of coaxial cable that has a loss of 3dB.
What is the effective radiated power from the aerial?

A) 10 Watts B) 20 Watts C) 30 Watts D) 40 Watts

[TIP: It often helps to draw a little sketch to show the power, losses & gains]

QUESTION D2
An oscillator has an output of -3dBm.
This is equivalent to:

A) 3 mWatts B) 3 Watts C) 0.5 mW D) -3 mW

QUESTION D3
An amplifier has an output power that is 200 times its input power.
What is the gain of this amplifier in dBs ?
[TIP: You could think of this amplifier as the equivalent of two “smaller” amplifiers of 100 times and two times]

A) 23dB B) 20 dB C) 10 dB D) 4dB

QUESTION D4
A pre-amplifier has a gain of 4dB
The main amplifier has a gain of 10dB
What is the overall gain when these amplifiers are connected in series ?

A) 2.5dB B) 6dB C) 14dB D) 40dB

QUESTION D5
The final valve in a transmitter has high tension supply of 300 Volts DC.
When operating in Class “A” this valve conducts 55mA.
What is the DC input power to this valve?

A) 165 Watts B) 16.5 Watts C) 58 Watts D) 52 Watts

QUESTION D6
A transmitter, having an output of 20dBW, is connected via 50 metres of cable to a dummy load. What power will be dissipated in the dummy load if the cable has a loss of 6dB per 100 Metres.

A) 14dBW B) 17dBW C) 23dBW D) 26dBW

