Coded Orthogonal Freq Div Mux

By G8MNY   (Updated Nov 08)
(8 Bit ASCII Graphics use code page 437 or 850)

Not knowing too much about it personally, here is some technical thoughts on transmitting this mode as I see it.

This Transmission mode is used for broadcasting e.g. DAB (1536 carriers) DRM & DTV-B Freeview TV (1707 or 6817 carriers now, incompatible 8k after 2013?)

It uses multiple carriers all phase modulated e.g. Quadrature Phase Shift Keying.

```
 │ │ │ │ │ │ │ │          QPSK      90°            /\     /\     /\
 │ │ │ │ │ │ │ │         on each 0°─┼─180°        |  |   |  |   |  |
─┴─┴─┴─┴─┴─┴─┴─┴──>F     carrier   270°         \ /    \ /    \ /
Even carrier spacing             Vectors       ───┴───────┴──────┴───────
                                            Each carrier sidebands nearly touch
                                             dependent on symbol rate (baud)
```

How electrically efficient is this mode? We know it is the best mode for bandwidth use, as it can use all the channel space right up to the edge compared to the less information/bandwidth efficiency of a single carrier QPSK mode such as Digital Sat.

```
         _
        /~ ~\              |~~~~~~~~~~~~~|
       |     |             │    COFDM    │
   _.-" QPSK  "-._         │   CARRIERS  │
──┼────────────────┼──    ─┼─────────────┼─
  Mux Channel Width        Mux Channel Width
     e.g. 30MHz               e.g. 8MHz
```

But there are problems, as any hams using PSK31 with just 2 carriers will tell you. The PA linearity is far more important than for speech amplitude modes let alone FM.

POWER OF 2 CARRIERS (e.g. PSK31)
With a PA say capable of 100W RMS/PEP that is 200W RF crest power, then one would intuitively think it could handle 2 carriers of 50W, but it CANNOT...

```
CREST           CREST V    CREST           CREST V    CREST           CREST V
POWER            @ 50Û     POWER            @ 50Û     POWER            @ 50Û
200 ┤    ..-..     ├ 100   200 ┤             ├ 100    200 ┤             ├ 100
100 ┤ .-~     ~-.  ├ 70    100 ┤    ..-..     ├ 70    100 ┤             ├ 70
 50 ┤/ 100W PEP  \├ 50      50 ┤ .-~     ~-. ├ 50      50 ┤    ..-..    ├ 50
 25 ┤  100W RMS    ├ 35     25 ┤/  50W PEP  \├ 35      25 ┤ .-~     ~-. ├ 35
 12 ┤              ├ 25     12 ┤   50W RMS    ├ 25     12 ┤/  25W PEP  \├ 25
  6 ┤              ├ 17      6 ┤              ├ 17      6 ┤   25W RMS   ├ 17
```

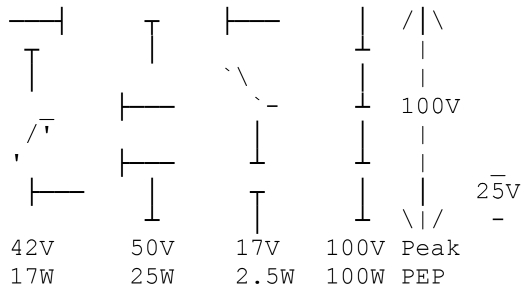
As you can see from the above a 100W carrier has a crest of 200W & a peak volt of 100V in 50Û. These are say the Max PA limits in my example.

Now consider the 50W carrier, it peaks 70V & to add another 50W carrier will need another 70V, for both you need 140V, but that is more than this PA can do. Only 2x 25W can be fitted in, that is 50V + 50V is OK. e.g. 50W mean 100W PEP.

Note that with two 25W carriers a typical meter will read something between 50W & 100W due to the slow detector time constants. A true RMS meter (heating effect type) will read 50W, & a proper peak reading meter 100W (scope display).

MORE CARRIERS

With 4 equal carriers, the maximum power is again quartered to 6.5W each, or 25W mean, but still 100W PEP (200W crest) is needed to handle the in phase peaks of the 4 carriers.



The carriers can be at any phase angle, on 4 different frequencies & quadrature phase angle modulated, but at some time the vectors will all add up in phase.

So it can be seen that ten 10V peak carriers can be used on this amp of 100V max. e.g. 10x 1W or 10W mean. (a 10V Peak carrier in 50Û is 1W)

From this the mean power must go down by the number of carriers, & each carrier power must go down by that number squared.

$$\text{MEAN POWER} = \frac{\text{PA MAX PEP}}{\text{No of CARRIERS}} \qquad \text{And each CARRIER POWER} = \frac{\text{PA MAX PEP}}{(\text{No of Carriers})^2}$$

BROADCAST

For DAB for example with 1536 carriers, means a 1kW amp could only do 651mW mean power, but still peaking 1kW PEP, & each carrier would only have a power 420uW, YES MICRO WATTS for no clipping!

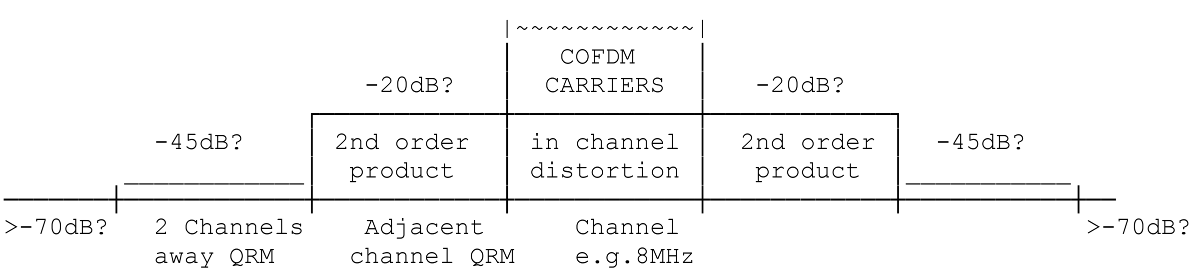
For DTV with 6817 carriers spread over 8MHz, a 33kW PEP amp could only do 4.85W mean power, & each carrier would be 710uW, but still 33kW PEP when all the carriers occasionally are in phase! This may only be for the odd RF half cycle, but distortion will occur if these levels are exceeded!

So a very large Tx aerial gain & large PA are need to get this Tx mode to give a respectable ERP.

This actually is a similar case to the old telecomms "SSB coax systems" where 1000s of phone channels were put down one amplified coax. Again large amps were needed & AGC systems to protect them from peak overdrive, as more phone calls were made, a reduced signal to noise occurred on each channel.

SPECTRUM GROWTH

With PA mixing due to non linearity the intermodulation product just GROW the spectrum like this with an amp run to the 1dB (10%) compression point..



It is very difficult to run a high power RF amplifier efficiently & very linearly at the same time!

I have been told the broadcast PAs are not run at a linear drive level at all, but driven until the spectrum growth/data error rate due to peaks hard clipping is troublesome! E.g. as the drive level is increased, 1st the out of channel mix products increase (2nd 3rd 4th etc.) then eventually there is enough inband mix products to cause the Rx bit error rate to go up.

RF FILTERING
Of course added RF filters either in PA stage or after a broadband PA, may reduce the apparent growth, but will not affect unwanted in channel distortion sidebands present in the passband from causing errors.

```
|       /~~"-"~"-"~~\
|      |             |
|     |               |
|    |                 |
| _./                   \._
+--------+---------+--------+
             8MHz
```

With COFDM linear phase or amplitude flatness of the filter is not too important (this why it is fairly immune to signal path ghosts), as long as each or most carriers can be decoded in their own narrow bandwidth, all is OK.

However signal to noise is important, especially from its own cross modulation QRM. RF channel filtering only cleans up adjacent channel mixing products, not in channel products.

Added losses & possible filter flash over must be a problem with peak powers 1000s of times greater than the mean if this approach is used.

AVOIDING IN PHASE
Because there is a serious PA overload problem if all or even most of the carries add up in phase, the coder software may be designed to alter/restrict the data that could cause this, but data options & data bandwidth loss or a time overhead will result if the method is used.

PA EFFICIENCY
It should be clear that amplifying all the carriers in 1 PA is not a wise way of going about multiple carrier transmission if there is to be no clipping. Ideally each carrier could have a linear PA (needed for QPSK) & a loss free RF directional coupler/adder used. But the short term cost of this complexity is excessive, & the system flexibility (no of carriers) will be hardware fixed.

Comment from Andy GM7HUD:-
In reality EER is used with non-linear amplifiers for real QRO solutions. In addition the I & Q components can be low level amplified to clipping & then filtered before that signal is passed to the linear PA stages. This can gain an extra 2dB in performance. Filtering the components before the main PA will results in a higher BER at the receiver due to in-band self QRM, but the coding used by the modulation scheme is normally robust enough to cope with this.

OLD ANALOGUE TV PAs
For main QRO stations these use a separate PA for the FM sound & a Linear PA for the Video. The video PA is also high level (current) modulated with line syncs to improve efficiency. The travelling wave type PA tube (several types) often have annular target anode rings of different HT voltages that greatly improving overall efficiency.

Using the TV PA efficiency definition of PEP/MEAN DC, efficiency of over 100% are common on the average picture content (not a black screen)! So you can get 33kW PEP from a 33kW UHF amp & it needs < 33kW of DC!

With this design of QRO PA, the main problem being the regrowth of unwanted lower sideband of the TV VSB signal. This is normally dealt with by a water cooled suckout filter in the PA tank circuit. As the sound carriers are added in with directional couplers after the linear PA there is no mixing problems.

ANALOGUE & DIGITAL TV Co-existing
With a clean QRO analogue Tx the adjacent channel emissions are generally very low something like > -60dBc. This has allowed the QRP digital TV signals to exist on adjacent QRO analogue channels providing the Rx is linear. The reverse is not possible, e.g. QRO Digital with QRP analogue adjacent!

Why Don't U send an Interesting Bul?

73 De John, G8MNY @ GB7CIP